UTILISATION OF WOOD-WASTE

E. HUBBARD

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SECOND REVISED EDITION

THE UTILISATION OF WOOD-WASTE

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THE UTILISATION

OF

WOOD-WASTE

BY

ERNST HUBBARD

TRANSLATED FROM THE GERMAN OF THE SECOND REVISED AND ENLARGED EDITION

BY

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WITH FIFTY ILLUSTRATIONS

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PREFACE TO THE FIRST GERMAN EDITION.

The rational utilisation of waste products forms at the present day, in all industries, a subject of the highest importance; by a correct utilisation of the by-products it is often possible to dispose of the main product at a lower price, or when prices are more and more lowered by competition, a profit may even be made from the by-products.

In all the industries which employ wood a quantity of waste material is obtained in such a form that its employment as wood either for construction or for fuel is not possible unless special appliances are made use of for the purpose; these, however, are in many cases not generally known, and the result is that a considerable amount of this valuable material is absolutely wasted. My object in the compilation of this book is to give information as to the most advantageous methods of utilising all wood-waste, and my endeavour has been to bring this treatise up to date with respect to practice and experience.

PREFACE TO THE SECOND GERMAN EDITION.

WITH the constant advance in the consumption of wood for building and other technical and industrial purposes, it naturally follows that the amount of wood-waste has also undergone an increase, and with the growth in the stringency of the conditions of production a greater value has attached to the utilisation of the waste. The appliances for the combustion of sawdust, partly direct for the sake of its calorific effect, partly indirect for the production of charcoal, the manufacture of alcohol and acetic acid from wood-waste, have been improved in many ways, whilst other modes of employment have made a considerable advance.

In revising my work, which in its first edition has met with a favourable acceptation, I have, to the utmost of my power, noticed all the novelties relating to the utilisation of waste materials, and have no doubt that the new edition will furnish valuable suggestions to those interested in the subject.

E. H.

1900.

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The various trades and industries which work up wood, from the simple mountain or forest saw-pit, in which the saw is worked by water power and where therefore no advantage is to be obtained from the combustion of the refuse as fuel, or from the large, well-arranged saw-mill, down to the furniture-maker and the cabinet-maker working on the smallest scale, the cutting up of tree trunks, the production of beams, and planks, etc., etc., all furnish large quantities of sawdust, which often occasion serious inconvenience to the producers. The amount of this waste product is often so enormous that neither storage room nor means of transport is available, and the substance, by lying in the open air exposed to all the vicissitudes of weather, either rots away completely or at least undergoes very considerable decomposition. The transport of sawdust, on account of its bulkiness, and the want of means of communication, is in many cases impossible, and many timber producers are glad if their neighbours will relieve them of an onerous burden, either cost free or for a small payment. In the immediate neighbourhood of railways and roads the value of sawdust is somewhat enhanced; nevertheless, even with these appliances, the packing for carriage involves difficulties, and the substance can neither be so utilised, nor so readily sold, as its real value merits.

Sawdust, in form and colour, is a very variable material. The product from large saw-mills, being for the most part obtained by the use of large saws, is coarse and fibrous, and is frequently mixed with fragments of wood and bark; moreover, in consequence of the use of unseasoned wood, it is often damp or even wet. The sawdust produced by those industries which make use of wood is generally finer, less fibrous, and drier, since it is the product of thinner saws with finer teeth; finally the waste obtained by working wood with the rasp is more or less floury. Only the sawdust of the softer woods (the coniferous woods, poplar, lime, etc.) is distinctly fibrous; that from harder woods (oak, beech, walnut) forms a coarser or finer powder, the condition of which depends nevertheless to some extent on the kind of saw used. The colour of sawdust depends on that of the wood from which it is obtained. That from hard woods is usually brownish, that from mahogany, reddish, etc.

Since the coarseness of the sawdust is dependent on the kind of saw used, and the degree to which the teeth are set, as also on the dampness of the wood, it follows that the percentage of this product yielded by the original timber is very variable; in large saw-mills, where tree trunks are cut up into baulks and deals, the proportion of sawdust will naturally be larger than in those industries which employ the wood already so prepared, and therefore it is from the former that the largest quantities of sawdust are obtained, and it is the owners of these mills who have the greatest interest in a favourable disposal of the material.

It is of the greatest importance in saw-mills that this waste product should be preserved in as clean a condition as possible, that shavings and chips should be kept out of it, and that it should not be allowed to be injured by getting wet.

The most obvious application of sawdust is, of course,

its use as fuel. If only small amounts have to be dealt with, it may be burnt in ordinary fire grates by throwing a little at a time upon a coal or wood fire which is in a vigorous state of combustion. The quantity thrown on the fire at once must never be large, and it must occasionally be loosened with a poker in order to give access to the air necessary for combustion. To burn larger quantities in the ordinary fire grates is difficult in consequence of the want of the proper air supply, for sawdust is a substance which sets closely together, and when in a damp condition is utterly unsuited for a fuel. Special furnaces and fire grates have therefore for a long time been in use for this purpose, whilst in recent times attempts have been made to consolidate the substance into briquettes before burning it, and have met with a fair amount of success. The furnaces and grates which have been suggested for burning this material, as well as the appliances for charging them regularly with sawdust, and for preventing the burning mass from collapsing, are described in a special section of this book, where the most recent improvements in these appliances will be found. A further step in the utilisation of this waste material is found in its combined employment as a fuel and as a source of distillation-products, such as acetic acid, wood-spirit, acetone, etc., which are obtained by subjecting wood to destructive distillation. In the same way, exhausted, ground or chipped dye-woods from extract factories and dye works, as well as spent tan from the tanneries, can be burnt in any of these furnaces, with a similar efficiency, so that in these industries very considerable sums can be saved, which otherwise would have been lost.

The use of sawdust in combination with binding and cementing substances, such as glue, albumin, blood, resin, to form plastic materials, such as the so-called *artificial wood*,

is already somewhat old and well known, though it is only quite recently that it has been discovered how to cement sawdust together so as to form a really firm decorative material, capable of resisting changes of temperature and damp, and in no respect inferior to expensive but fragile wood carvings. Amongst these materials should be mentioned that called *xylolith*, a substance of stony hardness, which, supplied in thin slabs of various colours, is employed for flooring, wainscot, and similar purposes, and has proved very satisfactory.

The production of *blasting powders and gunpowder* from sawdust has been repeatedly attempted, and although the results attained do not promise a very extensive consumption, some of the formulæ for this purpose may well find a place in this work. For the manufacture of *oxalic acid* sawdust is still almost the only raw material available, and affords a profit. The accumulation of sawdust in a great number of localities has, of course, given rise to numerous proposals for its utilisation, some of which, however, have never been put into practice.

Thus, in France, sawdust has long been used instead of sand for drying up ink. Sawdust has the advantage over sand that it is in no way injurious to books, pens, writing table, etc. And in countries where the minimum postage fee is restricted to letters under ½ oz. in weight, the use of the far heavier sand may easily cause a letter to be over weight. For this purpose the sawdust of hard woods, cut with fine saws, as for instance in cutting veneers, is chiefly employed. This is not used exactly in the state in which it is first obtained, but is passed through a coarse sieve so that splinters of wood may be taken out, and is then freed from dust by shaking it on an extremely fine gauze. As employed it is therefore in a finely granular condition, free from coarse particles and not dusty; the harder the wood the better is the product.

Sawdust for this purpose is commonly dyed and perfumed in order to give it a more pleasing appearance. The dyes used are those obtained from coal-tar; 3 to 5 parts of the selected dye are dissolved in 100 parts of water, the sawdust is stirred into the solution and thoroughly wetted therewith, so that a uniform dyeing of every particle may be ensured, and after taking out from the dye-bath it is dried in moderately heated chambers for the removal of the excess of moisture. Any desired tint can thus be given to the powder, after which it is perfumed by placing it, together with very small quantities of ethereal oils, in vessels which can be closed and rotated until the perfume is uniformly absorbed. This mode of utilisation is especially to be recommended to veneer cutters for working up their sawdust. If the sawdust from the various woods used in these workshops were collected separately, the mahogany and rosewood could be employed for dyeing the lighter woods. The dark woods could be boiled with water containing a little alum, and the filtered extract used for dyeing alder, cherry, or elm wood, thus communicating to these light woods a mahogany or rosewood appearance.

Sawdust of any sort may also be used in making plastic cements (stoppings) for filling up defective places in woodwork, and it is advantageous for this purpose to use the sawdust of the same sort of wood as that to be stopped up, rather than to dye another sort of sawdust so as to match the shade.

The use of sawdust as a *packing material* for fragile articles, such as those of sheet metal or glass, is too well known to require mention here; it may, however, be noticed that care should be taken to have it well dried and free from dust. The same is the case with regard to its use in a damp state for sweeping out the floors of dwelling rooms. Dry, clean sawdust is a good material both for packing and for preserving eggs, and is far to be

preferred to chaff, which is often damp and malodorous. Less known is its use in paint works, for cleaning the paint mills, utensils, cans, etc., from paint residues which cannot be removed with scrapers. The paint is completely removed, leaving the mills clean, and the metal work bright.

For the preparation of a substitute for bone ash, Maxwell Lyte proposes to mix mineral phosphates with peat, sawdust, tar, etc., or with animal substances such as blood, and to calcine and pulverise the mixture.

The low conductivity for heat possessed by sawdust is of importance, and has gained for it extensive employment. The intermediate spaces between the joists in houses may advantageously be filled with sawdust instead of with builders' rubbish, which is, often enough, deleterious to health. Its use as a packing material for ice chests and ice houses is well known, and it may also be used with immense advantage for preserving the warmth of green-houses.

The well-known linoleum is manufactured from ground cork refuse mixed with linseed oil and rolled out into sheets; instead of cork powder, sawdust has often been used, or rather the wood-meal obtained by grinding saw-dust between millstones, and, especially for the cheaper qualities, has given favourable results. Also in the manufacture of paper, wood-meal has here and there been used as a filling material instead of mineral substances. For laying down floors with cement plates, sawdust is better than sand, as it makes the floor warmer. When sawdust is mixed with tar-resin in various proportions, with the aid of heat, and the mixture is exposed to great pressure in moulds, a substance is obtained resembling wood, which can be cut, planed, bored, and polished, and which is very hard, tough, and imputrescible. The sawdust must first be baked until it is almost brown-black, which makes

it free from water. Plaster and cement planks (sawdust boards) may likewise be prepared by mixing plaster of Paris or cement with sawdust and water, and pouring the mixture into suitable moulds; these planks form a light but strong building material. Sawdust with plaster of Paris, or wood-wool refuse with plaster, forms a very suitable material for packing steam boilers, steam pipes, etc.

Combined with asphalt, sawdust is used in the damp-proof course of walls. Roofing felt intended for export is strewn with sawdust instead of with sand to diminish the weight and obtain greater elasticity.

Wood-cement is prepared from sawdust, glue, and water-glass (sodium silicate). The addition of sawdust to clay intended for brick-making produces light, porous bricks. These are used for partition walls, and are very bad conductors of heat. By mixing a very large quantity of sawdust with clay and kiln-burning the mixture, a cheap filtering material is obtained, which, as it contains wood-charcoal, serves as a disinfectant. Sawdust mixed with gas-tar forms an admirable damp course for the walls of buildings standing on damp ground. Mixed with balsam of sulphur it gives an elastic material, and, with asphalt and a little linseed oil, a harder mixture for coating damp walls and cold baths.

In burning black clay pipes, a layer of sawdust and then a layer of pipes are placed in a muffle, which may hold 500 to 600 pipes; the muffle is then luted and heated to a dull red-heat in a furnace for 10 to 12 hours. The sawdust is carbonised, and gives up its products of distillation, which are absorbed by the pipes and communicate a black colour to them. About 20 to 50 of the pipes are stuck upon a round disc furnished with pegs, and are held in the smoke of burning straw: they acquire an intense black colour, and are then polished with wax and a stiff brush.

In the manufacture of wall paper, sawdust and even

wood-meal, instead of the usual chopped wool, have been used for making low qualities of velvet paper, the previously dyed sawdust being sifted over the paper which has been first printed with an adhesive paste; also in other industries fine dyed sawdust may with advantage be employed instead of chopped wool. Wood-meal is used in the manufacture of artificial flowers, to imitate the pollen, and when dyed in pale soft shades has a very good effect.

Sawdust wetted with sulphuric acid is placed in stables to absorb ammonia, for which purpose it answers better than the gypsum formerly employed. For this purpose 1 part of sulphuric acid is diluted with 15 parts of water, the sawdust is soaked in the mixture, and after draining from superfluous liquid is spread on shelves in the stable. Every three days the supply of sawdust is renewed; that which is saturated with ammonia being thrown on the manure heap, the value of which is thereby increased.

As *litter* for *cow-sheds*, sawdust is superior to leaves or pine needles, as it is capable of absorbing more liquid than the latter, and nevertheless furnishes a dry bed for the beasts. Sawdust, especially that consisting of long fibres, saturated with animal excrement, makes a very good manure, because it rots easily.

In the preparation of composts for garden work sawdust is of great importance. To prepare it for use it is laid down in an open shady situation in heaps 75 to 100 cm. (30 to 40 inches) high, and turned over several times a year, until the whole mass is well rotted. This compost is lighter than leaf mould, and for some plants, as for instance orchids, may be used alone, or it may be mixed with cow dung or garden soil to make it heavier, or with heath mould or sand to make it lighter. Another use of sawdust is for the preparation of hotbeds, instead of the tan commonly employed. It gives a higher temperature

than tan, and maintains the heat for a full year. It is advisable to mix a little chopped straw with the sawdust to prevent it from becoming too consolidated, in which case the heat would not be given out sufficiently.

Far too little attention is paid to the applicability of sawdust for giving a loose texture to dense materials, and lightening heavy ones. Thus the well-known Laming's mixture employed for the purification of illuminating gas in gas works would be far too dense by itself, and has therefore to be mixed with a large quantity of sawdust to give it a coarse, open texture. Both sawdust and wood-shavings may be used for the purification of coal gas if they are soaked in a solution of copper vitriol and the gas is then passed over them. Mariot and Sugden proceed as follows: Instead of freeing coal gas from ammonia by passing it through sulphuric acid, it may be passed through vessels resembling dry lime purifiers, namely, boxes containing hurdles on which a loose material containing sulphuric acid is spread out. Sulphuric acid of 1·425 specific gravity is the most suitable for this purpose. This sulphuric acid is mixed with sawdust in the proportion of 84 parts of the acid to 50 of sawdust. The mixture is then heated to about 120° C., so that the sawdust becomes carbonised and the charcoal absorbs the acid. This yields a dry, porous material, which, when spread upon hurdles, allows the gas to pass readily. In charging the purifiers a layer of old material, already saturated with ammonia, is placed first on the hurdles in order that they may not be corroded by the acid, and the fresh mixture is then placed on this layer.

Croll employs for the purification of coal gas the residue of manganous chloride, from the chlorine stills, which he mixes with lime and sawdust, and exposes to the gas until it contains 30 to 40 per cent. of ammonium chloride, which can then be recovered by lixiviation or sublimation.

In the cementation process of making steel, the iron bars are packed with sawdust into an iron box, which is then closed with a clay luting and moderately heated for a longer or shorter time, according to the thickness of the bars. The steel obtained is melted in a closed iron (?) crucible under a layer of fresh sawdust, and may be poured into heated iron moulds.

The acetates of potassium and sodium are said by Sonstadt to be producible from the sulphides of the two metals by evaporating their solutions to dryness with sawdust and carbonising the mixture below a red-heat. The black mass is boiled down to dryness with milk of lime until a sample of the liquid is found, after filtration, to be free from sulphur. The whole quantity is then filtered, the filtrate evaporated to dryness and the residue gently roasted. The product is a tolerably pure acetate.

Mortar made with sawdust has repeatedly been advocated as a means of getting rid of moisture from damp walls. This mortar is prepared in the following manner: Ordinary slaked lime is thinned with water; sawdust is at once mixed with the lime, instead of sand, using such a proportion that the lime still retains the necessary binding power. A solution of water-glass may also be added to this mixture. Such mortar is not only recommended for the building of new walls, but also for plastering existing walls, and is said to be especially suitable for stucco, so that whole façades may be constructed of it. A very good roofing material may be produced by mixing melted coal-tar, flowers of sulphur, finely powdered hydraulic lime, and sawdust, and pouring the plastic material into moulds or rolling it out into slabs.

Mortelette has recommended sawdust for the prevention of boiler scale: the mixture employed consists of sawdust, soda, pine-wood charcoal, rye meal and clay.

Dyes are manufactured by Croissant and Bretonnière

from sawdust. The process consists in the removal of hydrogen from the wood by the action of sulphur at a high temperature. The products are called by their discoverers "organic sulphides," in which hydrogen is replaced by sulphur. These sulphides oxidise when exposed to the air, and give off sulphuretted hydrogen when treated with acids.

The manufacture of these dyes from sawdust is simple, requiring no complicated apparatus, and little labour; they are cheaper and more permanent than those most commonly in use; a pound of dye from sawdust, for example, costing only about half as much as the same quantity of logwood extract, and possessing four times the dyeing power.

The property which sawdust possesses of absorbing water is often utilised in public conveyances, omnibuses, tram-cars, etc., to keep the floor free from wet; sawdust is strewn on pavements in frosty weather, to prevent slipping and act as a safeguard against accidents.

Sawdust serves as a mild cleaning powder for tarnished silver, and beech sawdust as a polishing powder for gold. Sawdust may also serve as a kind of soap for the cleansing of house linen, the friction produced being efficacious for removing the dirt.

The Smith Consolidation Company, in Argo, undertake the conversion not only of small coal, but of sawdust, shavings, cotton wool fibres, etc., into briquettes, in order to utilise these substances as fuel. In the machine employed for this purpose a triple mould revolves round a vertical axis, and is so arranged that, when one of the moulds is under the charging funnel, the second is under the compressing stamp, and the third is being emptied by another stamp. The machine is capable of converting $1\frac{1}{2}$ tons of the sawdust from Weymouth pine-wood into blocks per hour. This process, the manufacture of

briquettes from wood-waste, has in quite recent times made very great progress, both sawdust and wood-shavings being compressed, either with or without binding materials, into hard masses which either serve directly as fuel, or are carbonised in closed vessels for the recovery of the products of distillation.

For the preparation of wood-pulp (according to Reth) the sawdust is disintegrated by an edge runner working in a stone bed; the material thrown out at one side is immediately replaced at the other until it has the desired degree of fineness. The edge runner is arranged exactly like the beating roller of a paper mill.

For the manufacture of short-fibred cellulose, sawdust may be treated by the soda, or sulphite processes.

F. W. Wendenburg prepares wood-meal fodder in the following manner: The wood (sawdust) is ground to a fine meal, to 50 parts of which there is then added $1\frac{1}{2}$ parts of rock-salt, and enough hot distiller's wash mixed with $\frac{1}{16}$ part of hydrochloric acid to form a thin pulp. After boiling for two hours this is ready for use as fodder, but it may also be dried and pressed into moulds, or can be baked in the form of dough.

Sawdust finds extensive employment in all the metal industries, especially for drying articles which have been treated with acids, no other substance being so effective as sawdust in drying and cleaning the objects and preventing subsequent oxidation (rust), or verdigris formation. Articles made of horn, ivory, tortoise-shell, and bleached bone cannot be better dried than in sawdust, since they then neither crack nor warp. For polishing metallic wares sawdust may be used with the greatest advantage; the articles to be polished are placed, together with a large quantity of sawdust, in rotating drums, and acquire their polish from the friction of the sawdust. The sawdust for this purpose must be perfectly dry.

A very useful product can be obtained by mixing sawdust and refuse wood-chips with the residues from the manufacture of turpentine and rosin, and pressing the mixture into moulds: it is used for kindling fires. The same waste materials have also quite recently been utilised in considerable quantities for the manufacture of carborundum and of calcium carbide.

A method of utilisation which will assume very large dimensions in the future, and which is perhaps even destined to produce a scarcity of sawdust, is the conversion of that substance into sugar and alcohol, if the difficulties encountered in carrying out on the large scale the processes elaborated on the small scale can be overcome.

There are, without doubt, still other methods of making use of sawdust, some of which are of secondary importance, whilst others have not been made public, and it is probable that in the future still further uses will be found for this material.

Most of the methods of utilisation which have been mentioned above may be applied to extracted dye-woods, etc., and in some cases, where large amounts of these waste materials are available, they may be re-extracted, and then utilised as fuel to evaporate the very weak decoctions so obtained, for which purpose ordinary fuel would be too costly.

A similar product, to which hitherto far too little attention has been directed, is tan (oak bark), the complete utilisation of which in tanneries is impracticable with the primitive methods of extraction generally employed, and which therefore still contains considerable amounts of tannin, which can nevertheless be wholly extracted by processes similar to that mentioned above. A process has lately been adopted in France, analogous to Schützenbach's method of extracting sugar from beet-root, which obtains all the tannin from oak bark in a perfect manner. A

large number of round tubs, about 2 metres (say $6\frac{1}{2}$ feet) deep and $1\frac{1}{4}$ metre (say 4 feet) in diameter, in each of which a second perforated bottom is placed 1 decimetre (4 inches) above the floor, are connected by pipes, each of which is inserted at one end under the false bottom of one tub and at the other 0·15 metre (6 inches) below the edge of the next tub. The tubs are filled with the bark, and water is run into one of them; the extract passes on to the second, third and fourth, etc., becoming stronger in its progress, and extracting less and less tannin from the charge in each succeeding tub. The strong solution is finally drawn off from the bottom of the last tub. Supposing n tubs to be in use, the bark in the first tub will have been extracted n times when that in the last tub has only been extracted once. When n tubs of water have been run upon the charge in the first tub that charge will have been completely exhausted. The last water is drawn off, and the spent tan thrown out. The tub is refilled with fresh bark and is then made the last of the series. In the same way each charge as it becomes exhausted is replaced by fresh bark, and the process goes on continuously. This process not only exhausts the bark completely, but furnishes the tanner with extracts of varying degrees of concentration.

Extracted bark and other tanning materials may further be employed for the manufacture of ink. The spent tan is treated with caustic soda, and the filtered liquor is mixed with green vitriol (ferrous sulphate) and exposed to the air. Spent tan may be very advantageously used as a fuel if it is mixed with a little nitrate of lead, made into briquettes with lime, and dried; such fuel is said to be especially suitable for heating railway carriages.*

* In Germany the passenger carriages are frequently warmed by stoves.—(Trans.)

A considerable quantity of spent tan is used for spreading on riding roads and in equestrian circuses; it is used in agriculture partly as a manure, partly for forming hotbeds and keeping up the warmth of greenhouses. A certain amount is used in pleasure gardens. Flower beds which contain tan mixed with the earth remain free from weeds, the soil is kept in a loose condition, remains damp in the dryest season without any need of watering, and is altogether free from the larvæ of the cockchafer. The growth of the trees is vigorous, branches are produced in abundance, and both leaf and fruit-bud formation are strong. Root production is also greatly augmented. Old trees growing in a tan soil are particularly fruitful and produce handsome fruit: standards exhibit the same result. By using spent tan, not only is the cost of weeding saved, but the roots are preserved from the attack of insects, growth and fruit formation are promoted, and therefore profit is increased.

When we come to consider more closely the methods by which sawdust, waste wood in larger or smaller fragments, extracted dye-woods, spent tan bark, nut-galls, etc., can be utilised, we find that the processes may be divided into two main groups, one of which may be called the *chemical*, the other the *mechanical* application. The chemical processes comprehend:—

1. Employment as fuel.
2. Dry distillation.
3. Treatment with various chemical reagents, for the production of cellulose, vinegar, alcohol, sugar, gum, oxalic acid.

The mechanical processes—which, however, must not in all cases be regarded as strictly mechanical, since many of them involved chemical changes—embrace:—

1. The production of artificial wood.
2. Employment in the manufacture of explosives.

3. Use as a means of producing porosity and lightness.
4. The manufacture of manure.
5. A variety of other methods of utilisation.

For the study of the mechanical processes a knowledge of the chemical constitution of wood is not necessary; on the other hand, such knowledge, as well as an acquaintance with the changes which occur when wood is exposed to a high temperature, or treated with reagents, is indispensable, and to these points we will here devote a few words.

Wood, chemically considered, consists of a number of different substances, the nature and proportions of which are dependent on the kind and the age of the plant from which it is derived. Broadly, we may distinguish in all varieties of wood two constituents, the woody fibres and the sap, the latter again consisting of water and the substances held in solution. The woody fibres consist of cellulose or cell-substance, which forms elongated cells grouped into bundles, and of lignin or the incrusting substance.

Cellulose belongs to the class of carbohydrates. To prepare it from wood, the wood must be treated with ether, alcohol, dilute acids and alkalis, and finally be copiously washed with water. Pure cellulose has the same composition as starch powder, and in many of its chemical relationships exhibits a similar behaviour, but the one substance has never yet been converted into the other, although from either it is possible to prepare a fermentable sugar, and, from this again, alcohol.

Experiments in this direction have indeed been attended with the result expected on theoretical grounds, but on the large scale, in consequence of the carbonisation of much of the woody substance and the large consumption of sulphuric acid needed, the process presents great difficulties. The action of hydrochloric acid on cellulose produces hydrocellulose and sugar (wood-sugar); nitric acid produces

nitro-cellulose; cellulose melted with caustic alkalis yields compounds of oxalic acid. When cellulose is burnt with free access of air it leaves an ash; if heated with exclusion of air it yields a series of the so-called fatty acids, also tar and charcoal.

Wood-sap contains, besides water and mineral constituents, a variety of soluble bodies, such as the carbohydrates (sugar, gum), albuminoids, and pectous substances; also, in individual species of plants, characteristic colouring matters, tannins, other extractive substances and resin.

When wood is burnt with free access of air, gases are produced, whilst a certain amount of heat is developed, and an ash is left which contains the mineral constituents of the wood, the carbonates of potash and of soda, carbonate and sulphate of lime and magnesia, phosphates, etc. In localities where timber is abundant, potassium carbonate (potash) may be manufactured from wood-ash.

If, on the contrary, wood is burnt with restricted access of air, or is heated in vessels from which air is excluded, which is the case when it is burnt in charcoal heaps, or heated in retorts, it undergoes a more or less complete dry distillation, and other products are obtained.

The dry distillation of wood commences at a temperature of 100° to 130° C., the first substance to distil over being water, the proportion of which naturally depends on the degree of dampness of the wood. The dampness of wood-waste will largely depend upon whether it has been kept under cover or been left lying in the open, and this will materially influence the amount of fuel necessary for its distillation. It is therefore advisable, where practicable, to subject sawdust to a preliminary drying before it is introduced into the distilling apparatus. As the temperature is raised from 145° to 500° C. the products obtained are: water, acetic acid, wood-spirit (methyl alcohol), and tar, as well as various gases, whilst wood-

charcoal is left in the retort. When the temperature is rapidly raised, acetic acid is the chief product; this must, however, be quickly removed from the heated vessel, or it will undergo further decomposition.

The products of the distillation of wood vary both in kind and in amount according to the degree of heat to which it is exposed. The higher the temperature the greater is the proportion of gaseous products, and it is usual not to exceed an incipient red heat.

With regard to the process of distillation itself, two different modes of operating must be distinguished :—

1. The wood (sawdust and other refuse) is subjected to distillation with the object of obtaining the largest possible yield of acetic acid and tar, with which object the distillation is carried on slowly and at a low temperature. Even in this case a considerable amount of gas is produced, which, however, for the most part consists of carbon dioxide and carbon monoxide, burns with a very feebly luminous flame, and can best be utilised for the production of heat by passing it first through a layer of incandescent carbon, by which the carbon dioxide is reduced to monoxide. This reduction takes place in furnaces of the kind in which the gases from the distillation are conducted into the space below the fire grate.

2. The wood is distilled with the intention of obtaining gas and tar, with but little acetic acid. In this case it is rapidly raised to a very high temperature; the greater part of the volatile products, consisting of carbon, hydrogen, and oxygen, is further decomposed with formation of hydrocarbons, which are partly liquid, partly gaseous. The gases so obtained have a higher illuminating power: whilst the yield of tar is considerable and that of acetic acid small.

The pyroligneous acid resulting from the distillation is a mixture of methyl alcohol, methyl acetate, acetone,

acetic acid and water; the tar contains benzene, toluene, xylene, cumene, naphthalene, paraffin, phenol, cresol, etc.

According to the temperature the products are:—

a. Gases. From 160° to 360°: carbon dioxide (carbonic acid), carbon monoxide, marsh gas (methane); from 360° to 432°: hydrogen, acetylene, propylene, butylene.

b. Pyroligneous acid. From 180° to 300°: formic and acetic acids; from 200° to 360°: propionic acid, butyric acid, valeric acid, caproic acid, methyl alcohol; from 250° to 360°: acetone, metacetone, acetic acid, methyl acetate, methylamine acetate and aldehyde.

c. Tar. From 360° to a red heat: the substances mentioned above.

The charcoal, acetic acid and methyl alcohol obtained by the distillation of sawdust have hitherto been regarded as the principal products, the tar being looked upon as a by-product, and the process of distillation conducted accordingly. Lately, however, more attention has been paid to the tar, and from it have been obtained benzene, toluene, and naphthalene, hydrocarbons which are extensively employed in the manufacture of artificial (or so-called "aniline") dyes. In carrying out a distillation it is therefore necessary in the first place to decide what products it is desired to obtain, and to arrange accordingly. To give further details respecting the products of distillation would carry us beyond the limits of this book, which is intended to deal only with the utilisation of wood-waste; the reader may be referred to the following special treatises on this subject: "Das Holz und seine Destillationsproducte" (Wood and its Products of Distillation), by Dr. George Thenius; "Die Verwerthung des Holzes auf chemischem Wege" (The Utilisation of Wood by Chemical Methods), by Dr. Jos. Bersch (2nd edition); and "Die

Fabrikation der Anilinfarbstoffe" (The Manufacture of the Aniline Dyes), by the same (published by A. Hartleben).

Altogether different are the products obtained when wood is acted on by chemical reagents. We have already seen that wood consists of two principal substances, cellulose and lignin (the incrusting substance). By suitable treatment—boiling with nitric, sulphuric, or hydrochloric acid, with caustic soda, with sulphurous acid, and with sulphites under pressure—the cellulose may be obtained more or less pure, the incrusting substances being dissolved out. In the decoctions there exist numerous gummy and saccharine substances, and many attempts have been made to bring these into use.

By boiling or heating with dilute hydrochloric acid, the cell walls of the wood become broken down, the incrusting substance is dissolved and converted into grape-sugar (glucose), whilst a substance called fibro-cellulose or lignose is left, which is more easily attacked and dissolved by alkalis than cellulose. The following are the results of some experiments in this direction.

In order to combine the production of grape-sugar and alcohol with that of wood-fibre, the first step was to ascertain the best proportion of acid to wood, and the most suitable concentration, in order to obtain a maximum quantity of sugar with a minimum quantity of acid. The following experiments were made with this object:—

A. 200 grams of sawdust (pine-wood with 15 per cent. of hygroscopic moisture) were boiled for 1 to 2 hours with 2 litres of hydrochloric acid of 5° Baumé = 1·04 specific gravity, corresponding to 162·2 grams of HCl. The sawdust, which acquired a reddish-brown colour, was thoroughly washed, the liquid neutralised with soda and mixed with lead acetate. An estimation with Fehling's solution showed the presence of 18·12 parts of grape-sugar (glucose) per 100 parts of wood

taken. The greyish-brown lignose dried at 100°, weighed 129 grams, corresponding to 64·5 per cent. of the wood taken. Erdmann gives for lignose the formula $C_{18}H_{26}O_{11}$, and gives the following equation for its formation from cellulose:—

$$C_{30}H_{46}O_{21} + 2H_2O = C_{18}H_{26}O_{11} + 2C_9H_{12}O_6,$$

according to which pure cellulose should yield 56·23 per cent. of lignose.

B. 100 grams of sawdust similarly treated with 1 litre of cold hydrochloric acid of 10° Bé. (= 1·075 specific gravity, or 150 grams of HCl) gave 25 per cent. of glucose and 51·6 per cent. of lignose. The colour of the lignose in the wet state resembled that of rotten oak; in the dry state it was reddish-brown. When washed with dilute soda solution the washings were dark brown, which is not the case with ordinary wood-fibre. In this treatment the soda solution penetrates into the cells in which hydrochloric acid is present. An evolution of carbonic acid gas takes place, which has a disruptive action on the fibres, and would perhaps serve as a preparation for their subsequent employment.

C. 180 grams of sawdust with 800 cub. centimetres of hydrochloric acid of 6·5° Bé. (= 1·048 specific gravity, or 76·8 grams of HCl), boiled for several hours, gave 20·83 per cent. of glucose and 62·22 per cent. of lignose.

Two experiments with fine oak sawdust (6·5 per cent. of moisture) gave—

Per cent. of glucose.	Per cent. of lignose.
13·22	62·75
15·43	66·11

The results of the three experiments with pine-wood were as follows :—

	HCl used per 100 parts of wood.	Glucose obtained per 100 parts of wood.	Glucose obtained per 100 parts of HCl.
1	81·1	18·12	22·37
2	150·0	25·00	16·66
3	42·6	20·83	48·89

It is said that these proportions are already employed in practice, and that after the acid solution of the sugar has been neutralised with lime down to 0·5° of Lüdersdorf's acid scale, a fermentation of the mixture for 24 hours followed by distillation gives from 450 kilos. (9 cwt.) of sawdust, 26·5 litres (5·8 gallons) of 50 per cent. alcohol, free from any turpentine odour and of agreeable flavour.

CHAPTER II.

THE EMPLOYMENT OF SAWDUST AS FUEL, WITH AND WITHOUT THE SIMULTANEOUS RECOVERY OF CHARCOAL AND THE PRODUCTS OF DISTILLATION.

The proportion of combustible matter in sawdust, and the calorific effect obtainable from its combustion, are exactly the same as those of the wood from which it was derived, since sawdust is nothing else than wood-fibre very finely subdivided by artificial means. However, when used as fuel, sawdust has the property of forming a layer which is very impervious to air, of falling through the fire grate in consequence of the fineness of its particles, and of giving off a large amount of water-vapour which impedes vigorous combustion. The compression of the heap of material prevents the due access of air, the layer of sawdust becomes carbonised at the surface, and finally the heap becomes covered with ash to such an extent that combustion is completely arrested unless the heap is continually being turned over. When sawdust is used for heating purposes the only object is to utilise its calorific power. If the sawdust is made up into briquettes with peat, tan-refuse, coal slack, etc., and thrown in this form upon the fire grate, its combustible matter can be more efficiently utilised than when one tries to burn it in a loose condition. The making up of the sawdust into solid blocks nevertheless makes it more expensive, and it is also difficult to find a completely suitable binding material, which will aid rather than impede the combustion, unless the substance is compacted by employing an exceedingly high pressure instead of using

a binding material. The binding material must be so selected that it not only holds the sawdust together during transport, loading, and unloading, but possesses sufficient resistance to heat to prevent the briquettes from falling to pieces during combustion, and thus reproducing a bed of fuel impervious to air. Up to the present time there has been very little practical use made of these compacted sawdust briquettes; attention has rather been directed to devising forms of furnace which will burn the loose sawdust directly. A better mode of utilising sawdust as fuel is to mix the dry sawdust with $\frac{1}{6}$ of its weight of coal; and it is of special importance in using this material to take care to have a vigorous coal fire as a basis on which the sawdust can be thrown. With such a coal fire for a basis the following advantages are obtained: (1) The evaporation of the water in the sawdust—the proportion of which objectionable constituent may vary from 25 to 40 per cent.—is much accelerated; (2) the combustible gases are more rapidly evolved and burn with a flame, whilst the carbon, being converted into carbon dioxide and not into carbon monoxide, gives a greater heating effect.

A new process for converting sawdust into briquettes aims at heating the substance so far that the resin naturally contained in the wood (therefore with soft woods only) is softened, and then, without any further binding material, pressing it into moulds at very high pressure. A fuel prepared in this manner is easily transportable, has an essentially higher heating power than brown coal, and is equally suitable for household and for technical use.

It is obvious that for the advantageous employment of sawdust as a fuel the first consideration is to give an appropriate form to the fire grate. The sawdust is generally thrown on the grate in a somewhat thick layer, and the spaces between the fire bars, which serve as channels for the supply of air, are to a great extent choked by it. But

since combustion without a sufficient supply of air is quite impossible, it is obvious that the grate, in all patterns of furnace, must be so constructed that there shall be no deficiency of oxygen. The proportional area of the fire grate must be adapted to the nature of the fuel to be burnt on it, for a very different area will be required for burning on the one hand good coal, and on the other hand sawdust; the correct proportion must therefore be adapted to the amount of steam which it is required to raise.

No especial difficulties either in the construction of the grate or the furnace will be encountered, if only small amounts of sawdust have to be burnt in combination with other fuels; nothing is then necessary but from time to time to throw upon the coal fire, when it is in a vigorous state of combustion, a few shovelfuls of the well-dried sawdust, and let it burn without disturbance, an operation which can easily be brought into practice in places where exhausted dye-wood, tan, etc., are obtained as refuse in amounts which it is easy to dispose of. The matter is, however, quite different when it is necessary to burn sawdust either almost or quite alone.

With this end in view a considerable number of furnaces for burning sawdust have in the course of time been invented, the chief of which will now be more minutely described and elucidated by figures. These are the Kraft sawdust furnace, the Lundin furnace, Koch's sawdust furnace, Walter's furnace for making wood-tar, the André furnace for sawdust, the arrangement of Niederberger and Co. for burning damp wood-refuse and sawdust, Godillot's pyramidal grate for pulverulent fuel, gas generators and condensers for sawdust, and the Zwillinger apparatus for carbonising sawdust, as well as a number of newer patterns which will also be minutely considered. These designs are exceedingly various in principle; they may nevertheless be easily divided into two groups:—

1. Types which are designed merely with the object of burning the sawdust for heating purposes, and in which therefore no value is attached to the condensation of volatile products derived from the wood.

2. Types which are chiefly designed to accomplish the latter object, and with which, besides tar, wood-spirit, acetic acid, acetone, etc., a serviceable charcoal is also to be obtained. In furnaces of the second class it is especially recommended that the gas resulting from the distillation should be conducted into the fire. The apparatus of Niederberger & Co. allows the employment of damp material, so that such substances do not have to be dried first, which would require at least space and labour for turning the material over, even if no special drying arrangement were needed. Godillot's pyramidal fire grate also allows damp material to be employed. Zwillinger's furnace is constructed on very ingenious principles: the sawdust and other wood-refuse are not burnt directly, but are carbonised in closed vessels, so that all the volatile products of the dry distillation of wood can be condensed, and the gases used either for lighting the works or for heating purposes, thus utilising very completely this waste material, and proving extremely advantageous in localities where much timber is felled and cut up. In fact Zwillinger's furnace has already proved practically successful in several places, especially in Galicia and Silesia, the tar and pyroligneous acid being either worked up on the spot or sent to chemical works. Weiss and Güttler have proposed to carry out the decomposition of the wood in an atmosphere of hot gases, heating the retorts from outside. Waisbein devised a plan of decomposing sawdust in an atmosphere of producer-gas, whilst Güttler designed an apparatus for the preparation of powdered charcoal, in which the external heating of the retorts was dispensed with. A. Gustav carbonises wood or wood-refuse by in-

troducing the material into tubes or channels, and heats it under pressure, whilst allowing the evolved gases to escape gradually, so that a continuous solid carbon rod is formed which retains its coherence after removal from the tube or channel. G. Scheffer has constructed a special furnace from ordinary bricks, in which wood refuse of all kinds, such as spent tan, sawdust, etc., is submitted to dry distillation by the partial, incomplete combustion of the substances themselves. In trials carried out on the large scale with tan containing 24 per cent. of water, complete combustion was effected. The vapours evolved from the furnace pass first through acetic acid saturated with lime, and then rise through a coke tower down which milk of lime is allowed to flow. The gases which escape finally are either burnt like producer-gas, when there are several furnaces, or are allowed to escape into the chimney. Where there is no chimney shaft the necessary draught for the distillation furnaces is produced by a special furnace in communication with them. F. Frisch, of Niederweise in Saxony, likewise manufactures pyroligneous acid from spent tan, etc. Readfield and Halliday work up sawdust, and obtain a result which does not in any way agree with the statement in chemical treatises that resinous woods yield proportionally little acid. Eight retorts of 45 cm. diameter (18 inches) produce in 24 hours as much pyroligneous acid as 16 simple retorts of 1 metre ($39\frac{1}{4}$ inches) diameter. The wood-charcoal which is produced from the sawdust is employed in large amounts for the manufacture of artificial manure, and possesses in a high degree the property of deodorising the urine used in dye works, furnishing therefore an easy means of getting rid of the disagreeable odour which escapes from the urine tanks.

Kraft's Sawdust Furnace.

This furnace is shown in Figs. 1 to 3; Fig. 1 showing a longitudinal section through the middle; Fig. 2 a transverse section, and Fig. 3 a horizontal section. The apparatus consists of retaining walls, A, B, of any desired

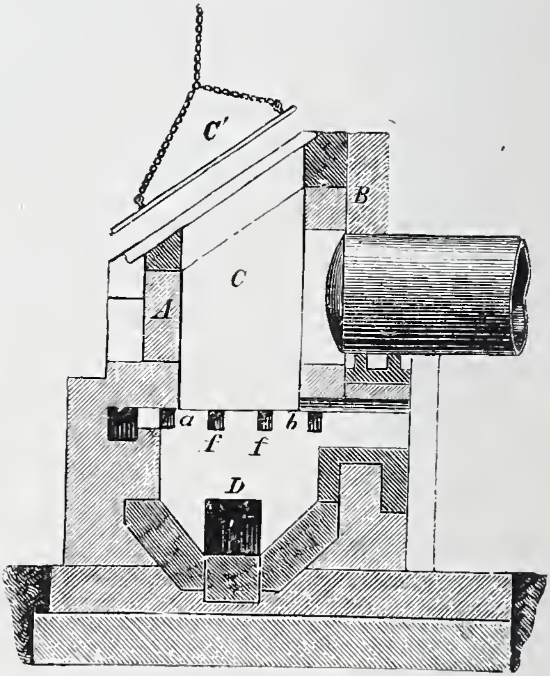

Fig. 1.—Kraft's Sawdust Furnace (Longitudinal Section).

form, the simplest being an elongated quadrilateral, which is also that most easily constructed. The wall B is usually already existent, being that of the steam boiler or furnace hearth. The fuel is introduced from above through the opening C, which is closed by a sheet-iron cover as soon as the workman ceases to stoke. The lifting of this cover is assisted by a counterbalance. At the level, *a*, *b*, the fireplace is widened out by the walls A and B being re-

cessed. The lower part of the apparatus forms an ash-pit, and is furnished with two openings, D, which can be closed by tile or sheet-iron ash-pit doors. These openings are closed during the working of the apparatus, and are only opened for the removal of ashes or clinker. Each of the ash-pit doors may have a small opening through which air can be allowed to enter if, for any reason, the combustion requires to be invigorated. In the front part of the

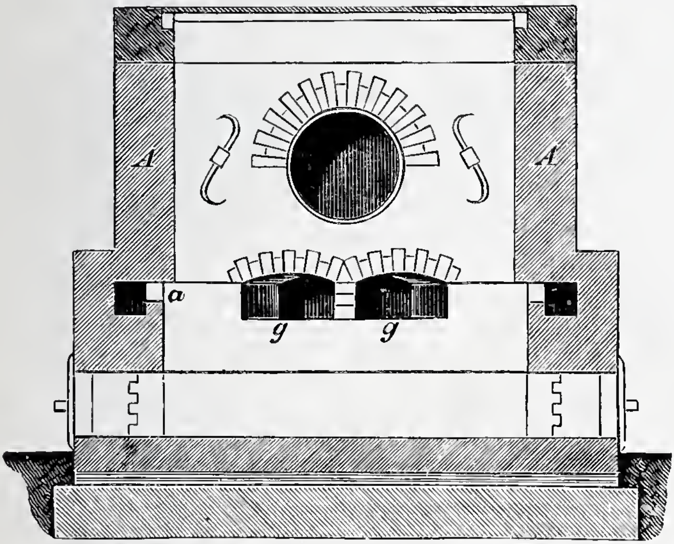

Fig. 2.—Kraft's Sawdust Furnace (Cross Section).

apparatus there is a channel, E, which passes through the whole length of the brickwork, and is closed at both ends by wooden or iron discs. This channel communicates with the combustion chamber by a number of holes, *f*, *f*, through which a supply of air is introduced. The combustion takes place in the lower part of the apparatus, and the gaseous products of combustion pass through the opening below the boiler or through the working hearth. The fuel burns therefore between the openings *f* and *g*. It often

happens that arches form in the heap of sawdust, and in that case the whole concave surface of the arch is in a glowing state; small fragments of the burning matter detach themselves from the lower surface of the arch, fall to the floor and burn in the ash-pit.

As it frequently happens that these arches collapse, the combustion would thereby be arrested or hindered if it were not for the recesses *a* and *b*, which keep the operation going. If the air is prevented, by the collapse of an arch,

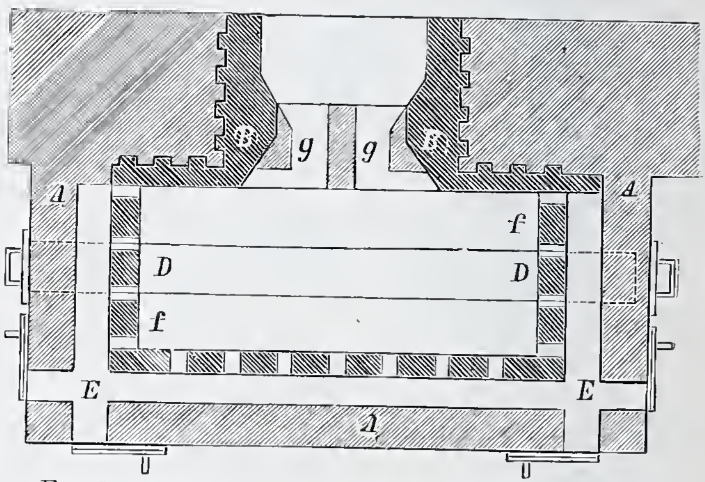

Fig. 3.—Kraft's Sawdust Furnace (Horizontal Section).

from passing directly from *f* to *g*, it takes a circular course round the apparatus and continues the combustion of the material. A lofty chimney, or a fan, produces a sufficient draught for this purpose, and in a few minutes the combustion reattains its original intensity. The walls of the furnace must in fact be of such a height that the collapse of such an arch does not uncover the channels *g*, *g*. The action of the furnace is a continuous one; the fuel both takes fire and burns readily, because the lower walls are very hot and radiate heat from all sides. The com-

bustion is also a complete one, because the openings *f*, *f*, produce a very intimate admixture of combustible gases with atmospheric air at a high temperature. Along with the finely divided fuel (sawdust) larger fragments of the same may be burnt. Thus, in a trial made at a paper mill, wood billets were burnt along with the sawdust and with as good a result as with sawdust alone.

After a short time the fire-bricks which line the channels *g*, *g* become white hot, and if dry sawdust is being used the temperature rises to a point which is sufficient for any furnace operation.

The work of this furnace is continuous and is easily regulated; it will burn the very worst kinds of fuel, such as rotten tree-trunks, pine needles, etc., whilst it can be erected cheaply, and, as the following experiments show, seems to present very great advantages. In an experiment on raising steam in a steam boiler, the combustible material consisted of sawdust and shavings: the former was $\frac{1}{3}$ pine, $\frac{2}{3}$ oak; the latter, $\frac{1}{2}$ oak, $\frac{1}{4}$ pine and $\frac{1}{4}$ poplar. The trial lasted 15 hours. The fuel burnt amounted to 1544 kilograms of sawdust and 715 kilograms of shavings, or a total of 2262 kilograms. The quantity of water used amounted to 3680 litres. The temperature of the feed water was 18° C., and the pressure of the steam produced was 4·95 or 5 atmospheres (75 lbs. per square inch). The substances burnt as fuel contained 38·6 and 27 per cent. of water respectively. The fuel lost therefore 791 kilos. of water. Assuming that the heat required to evaporate this quantity of water in the furnace would have evaporated an equal quantity in the boiler, we may take it that $2262 - 791 = 1471$ kilos. of combustible matter evaporated $3680 + 791 = 4471$ kilos. of water, or 3·04 parts of water for 1 part of combustible material.

Another experiment with an 8 to 10 horse-power steam boiler gave the following result: The substances to be burnt

were merely air-dry, and consisted of 413 kilos. of pine bark, 154 kilos. of oak sawdust, 18 kilos. of oak shavings, and 152 kilos. of oak waste, or in all 717 kilos. The engine ran for 10 hours and drove 2 water pumps, 3 circular saws, 2 planing machines, and 2 drilling machines. The boiler was fed with water of 20° C., and a steam pressure of

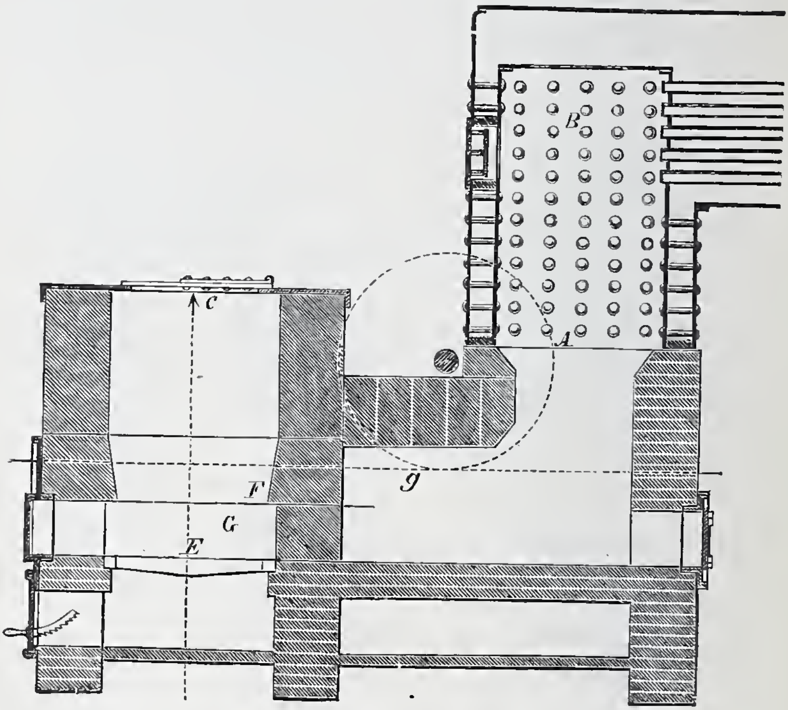

FIG. 4.—André's Sawdust Furnace (Section).

75 lbs. was obtained. Although this experiment is an incomplete one, it sufficiently demonstrates the value of the apparatus.

André's Furnace for Sawdust.

This furnace is a modification of that of Kraft, and differs from the latter in having the abruptly widened

combustion chamber replaced by one which increases gradually from above downwards, and also by the introduction of some structures of prismatic form, built of firebricks, into the lower part of the combustion chamber. In Fig. 4, A, B represents the front of the boiler which is to be heated. The material to be burnt is introduced from above into the chamber, C, D, and falls on the prismatic blocks, F, F, situated above the fire grate, E, which may be replaced

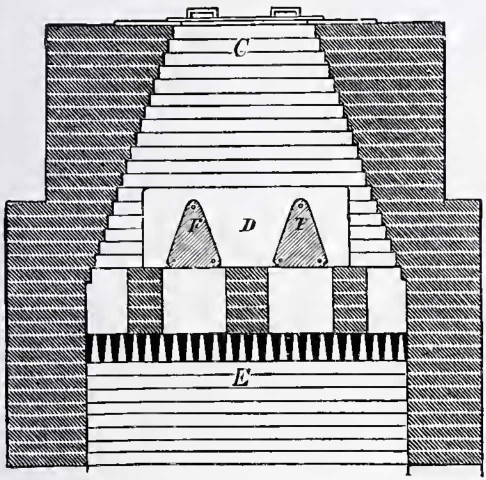

FIG. 5.—André's Sawdust Furnace (Cross Section through Combustion Chamber).

by a small arch. The principal combustion takes place in the chamber G with the air which enters from below the fire grate. With ordinary boilers this chamber G can be dispensed with.

The following experiments on the efficiency of this furnace have been made:—

1. Spent tan burnt in 12 hours, 1420 kilos.; this had for several weeks been kept on the top of the boiler and was thoroughly dry. Water evaporated 1·85 kilos. per

kilo. of tan; temperature of the gases at throat of chimney, 256° C.

2. Material consumed in the course of 12 hours, 340 kilos. of tan, and 1025 kilos. of sawdust. Water evaporated 1·29 kilos. per kilo. of fuel; temperature of gases, 250° C.

3. Material burnt in 12 hours, 414 kilos. of coal. Water evaporated, 4·54 kilos. per kilo. of coal; temperature of gases, 250° C.

Koch's Sawdust Furnace.

Koch's sawdust furnace is simple in construction, and when used in tanneries for burning spent tan as fuel may also be employed for sawdust and peat. The problem to be solved was the combustion of a wet pulverulent or granular material without previous drying or agglomeration, and also without having to force the air through the fire grate by mechanical means. Spent tan is a substance of this character; it is thrown out of the tan-pits saturated with water and in such a finely divided condition that it resembles sponge, and rarely contains granular fragments as large as a pea. In this condition it would be impossible to burn it on an ordinary grate without previous drying in the air, which would require a large space.

In one particular case this apparatus was employed for heating steam boilers, and the tan, although pressed, contained 40 per cent. of water.

The furnace consists essentially of a rectangular pit about $5\frac{1}{4}$ feet long, 40 inches wide, and 4 feet deep, the bottom of which contains two fire grates 18 and 20 inches wide and 40 inches long. The front wall of the fireplace has two doors for cleaning the grate, and two flues for carrying off the products of combustion. Two arches are thrown across the combustion chamber about 12 inches above the fire bars, leaving openings at the

sides 8 to 12 inches wide between the arches and the walls of the chamber, for the descent of the fuel. The upper surface of these arches is roof-shaped, the ridge running parallel with the fire bars. Iron bars are also stretched across the chamber, to obstruct the fall of the fuel and prevent it from settling down in a dense mass. The wet tan, thrown into the furnace, falls first on the upper surface of the arches, where it dries as it slides down towards the sides, and having passed through the side openings, it is delivered on to the fire grate in a perfectly dry condition. It there forms a layer 3 to 4 inches thick, which burns freely. There is no necessity for keeping a cover on the combustion chamber whilst the furnace is in use, but when work ceases in the evening the top is closed by cast-iron plates, the chimney, fire-doors, and ash-pit being likewise closed. By this means a dull red heat is maintained during the night, and when fresh fuel is added combustion recommences immediately. In cases where the substance to be burnt contains other volatile products than water, the ash-pit may be closed and the air for the combustion obliged to pass through the mass of fuel from above downwards. In this case, however, the water-vapour which is drawn into the flues with the products of combustion reduces the heating effect considerably, and, before making any alteration in the original arrangement, it is desirable to consider which is the better mode of burning a material containing a determined proportion of moisture.

Sawdust and Tan Furnaces.

The furnaces shown in Figs. 6 and 7 are intended for dye-woods, tan, and sawdust. If the wet materials are well pressed before use they can generally be employed as the sole fuel, without any admixture of coal.

Fig. 6 shows the fireplace of a Cornish boiler; the grate rises at both sides to meet the channels for the descent of

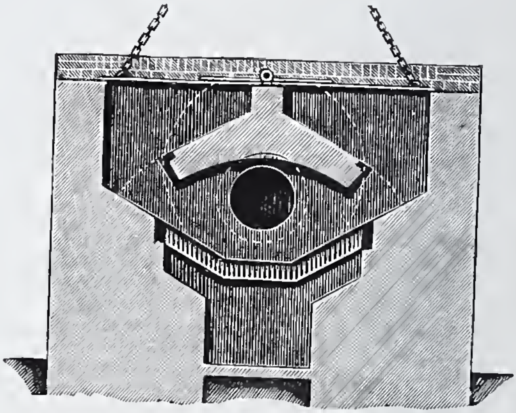

Fig. 6.—Furnace for Burning Sawdust or Tan for Heating a Cornish Boiler.

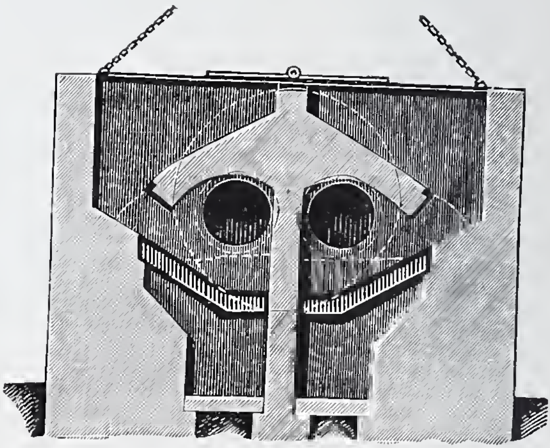

Fig. 7.—Furnace for Burning Sawdust or Tan for Heating a Lancashire Boiler.

the fuel. These channels widen out to large hoppers, which can be closed by a cover.

The fuel is charged into the hoppers and is conducted to the grate through the side channels, for which purpose doors are constructed in the front wall of the fire chamber.

Fig. 7 shows a similar construction for a Lancashire boiler. In this case the fire grate is divided by a partition wall which serves both to strengthen the structure and to regulate the distribution of the fuel over the grate area, which in this case is wider. These furnaces are adapted

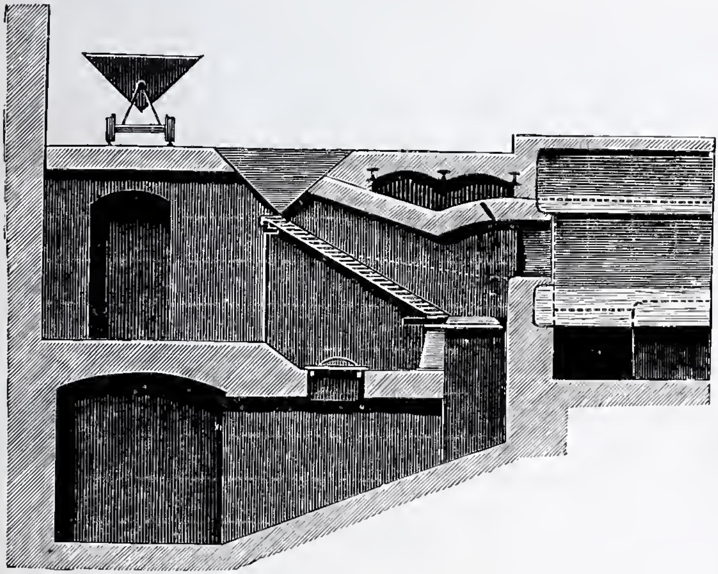

Fig. 8.—Sawdust and Tan Furnace, with Step Grate and Truck for Conveyance of Fuel.

either to steam boilers with internal flues, or to boilers which are heated externally. In the latter case the fireplace must extend 5 to $6\frac{1}{2}$ feet in front of the boiler.

The furnace shown in Fig. 8 is fitted with a step grate, such as is used in large works where a number of boilers are arranged side by side. The fuel is brought in trucks

running on tram lines, and is shot from these into a hopper from which it can be brought down to the grate by a rake.

This method of feeding, as well as the arrangements for

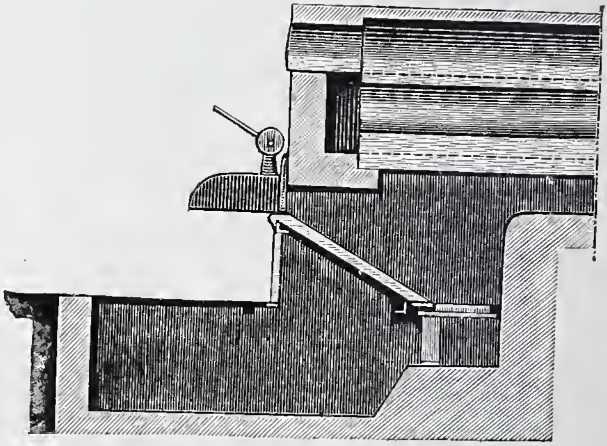

FIG. 9.—Sawdust and Tan Furnace with Step Grate and Feed Plate.

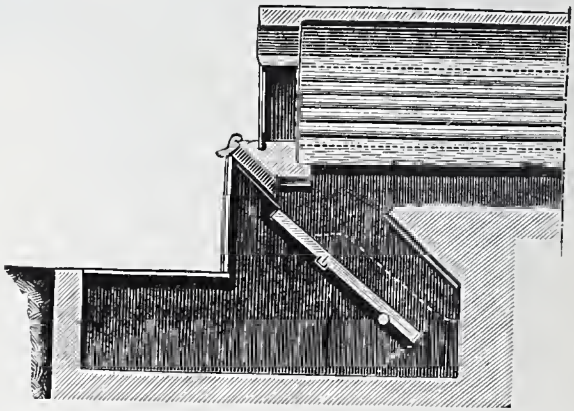

FIG. 10.—Sawdust and Tan Furnace with Step Grate and Fuel Hopper.

the removal of the ash, are very suitable for large establishments; but for small works, where there are only one or two boilers, it would not pay for the cost of construction.

The step grate may, however, be used in a simpler form of furnace, the fuel hopper being replaced by a feed plate, from which the fuel is thrust from time to time towards the grate with a hoe.

In Fig. 11 a construction is shown in which the fuel is thrown into a shaft, at the bottom of which it is carried forward by an endless screw to the fire grate. This is a very costly construction, on account of the mechanical

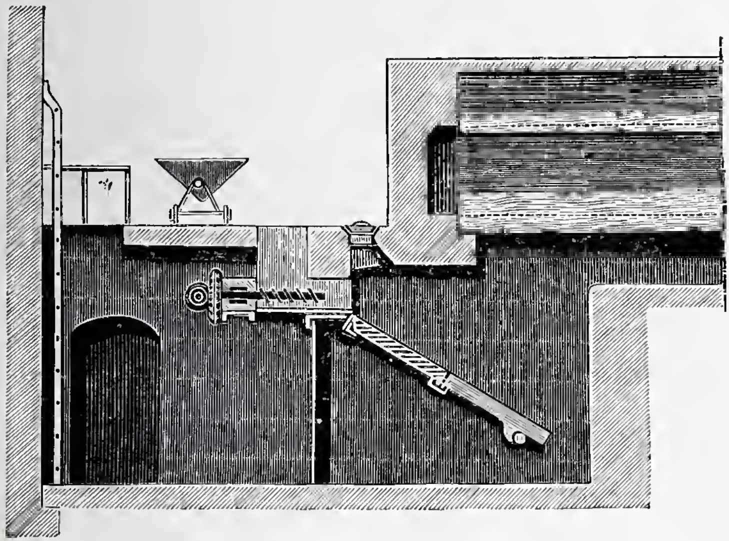

FIG. 11.—Sawdust and Tan Furnace with Step Grate and Charging Slot.

complication and consumption of power, and will not, as a rule, prove remunerative.

Respecting the above forms of furnace, the following remarks may be made: In most furnaces it is an essential condition that fresh fuel should be placed on the grate only at such a rate as suffices to replace that which burns away. When the fuel is fed to the grate by hoppers or shafts this condition is not fulfilled, for in the narrow parts of these hoppers or shafts the material is found to become

tightly packed, in the parts indicated by the dotted lines *a* in Figs. 6 and 7.

Unless the stoker is constantly stirring the fuel, it burns down on the bars and leaves free spaces through which an excess of air enters and cools the gases. The steam pressure falls; the stoker is obliged to drive the fire, and usually throws a large quantity of fuel on the grate. Then, in consequence of the layer of fuel on the bars being too thick, the air supply is deficient, combustion is imperfect and smoke is produced. These disadvantageous conditions are repeated at longer or shorter intervals, according to the care bestowed on the stoking: in addition, cold air obtains entrance to the fireplace whenever the fire-doors are opened for the purpose of poking the fuel.

In the earlier forms of furnace mentioned above, the rate of addition of fresh fuel is entirely dependent on the greater or less attention which the stoker gives to the work. Every time fresh fuel is thrown on, it lowers the temperature; and the admission of cold air when the fire-door is opened has the same effect. However careful the stoker may be it is impossible for him to keep the fire grate covered with an equally thick layer of burning fuel all over, or to avoid smothering the burning material by the addition of the fresh fuel, or to regulate the air supply properly.

The arrangement in Fig. 11 is designed to provide for an automatic supply of fresh fuel, independently of the stoker, but it does not altogether avoid the above defects. The supply of fuel by the action of the screws is only regular if the material itself is perfectly uniform. With a material of uneven size there is a tendency for open spaces to form on the fire grate, and the consumption of steam is never so regular that the supply of fuel to the grate will exactly keep pace with it; hence, at times, the air supply

is either in excess or deficiency. The arrangement is likewise costly and complicated.

None of these arrangements supplies the combustible material exactly at the rate at which it burns away, and this leads to a waste of fuel; the escape of the invisible gas, carbon monoxide, by the chimney being as much a loss of combustible matter as the production of smoke and soot. On the other hand, when the air supply is in excess, the draught takes place principally through the uncovered places on the fire grate, whilst the thicker layer of fuel at other spots will be in a comparatively sluggish state of combustion.

Furnace of Herm, Böttger & Co. of Dresden, for Sawdust, Dye-wood, Tan, etc.

The principle of this furnace is the establishment of the correct proportion between fuel and air supply, and the intimate admixture of the fire-gases in the combustion chamber. The former object is attained by an automatic conveyance of the fuel to the grate, the latter by appropriate subdivision of the gas currents in the combustion chamber. By this means a more complete utilisation of the combustible material is attained, and the formation of smoke and carbon monoxide, if not altogether prevented, is reduced to a minimum.

The arrangement of the individual portions of the furnace aims at fulfilling this fundamental condition. The grate, which consists of several portions, and is laid with a certain slope, receives the fuel from a hopper, and so distributes the layer of burning material that the air obtains proper access to it. The fuel hopper, which is placed at the upper part of the fire grate, is so constructed that neither in the hopper nor at its junction with the fire grate can the fuel become packed. On the contrary,

it allows the fuel to fall gradually on the grate by its own weight as fast as it burns away.

The fireplace is surrounded on four sides by brick walls at definite distances apart, with openings so arranged that the gas currents are subdivided and intimately mixed, thus ensuring the complete combustion of the hydrocarbons and carbon monoxide evolved from the layer of fuel.

The fuel hopper is replenished from time to time to prevent the amount of burning material on the grate from undergoing diminution; the layer of fuel on the sloping face of the grate is in a full state of combustion over the lower two-thirds of the grate area, whilst at the upper part water-vapour and combustible gases are escaping. The combustion is a gradual one; the drying of the material takes place in the hopper, and at junction of same with the grate; the most intense combustion goes on in the middle, and the complete combustion at the lower part of the grate.

The principal advantages of Böttger's furnace are as follow:—

1. The proportion between combustible matter and air supply is the most favourable one, and the gases are thoroughly mixed.

2. The evolution of smoke and carbon monoxide, if not completely avoided, is reduced to a minimum, and consequently the utilisation of the combustible matter is on the average 30 to 45 per cent. higher than in other cases.

3. The feed, however large the amount required of fuel, is simple and appropriate, and the labour small.

4. The stoker has a complete view of the fireplace, and in most cases the fire maintains itself, even if unattended for more than 24 hours, so that there is no need to relight every morning.

5. The fire requires less frequent stirring, and less chimney draught as a rule than in other furnaces.

6. The parts exposed to the action of the fire suffer less injury, and the fire-brick lining is of a simple character, consisting of smooth walls and arches which are easily constructed.

Sawdust Furnace for Production of Gas.

An improvement in the utilisation of sawdust may be effected by heating it in an atmosphere of certain gases; and the experiments which have been made in this direction have given good results as regards both the products of distillation and their yield, and the quality of the charcoal obtained. The gas employed may be either that derived from the sawdust itself or ordinary coal gas introduced into the retort from outside.

In experiments made with coal gas, the gas was passed into the retort at a certain pressure, and had the effect of removing the products of distillation more rapidly from the region of high temperature. The results obtained were favourable, but the decomposition of the products of distillation could only be partially prevented. In consequence of this, the method was altered so that the heat, instead of being applied to the material after issuing from the containing retort, was generated inside in direct contact with the substance to be distilled. All the gases employed in this manner must be completely free from oxygen, in order that no loss of the valuable products of distillation may take place.

One of the older arrangements is shown in Figs. 12 and 13. The furnace is constructed of slag-bricks with an inner fire-brick lining, and the heat obtained from it is employed in roasting the ore in a copper refinery. The first gas producers constructed were furnished with charging cylinders 3 feet in diameter, since the consolidation of the fuel by the formation of tar was feared; but

with these a loss of gas was found to be unavoidable. At first the cylinders were closed by cast-iron covers, but small explosions were liable to occur in the gas tubes, especially with an excess of air in the ore furnace. To ensure equable distribution of the fuel in the producer a sheet-iron tube, *a*, is fixed to the cover with screws. A layer of the combustible material 5 to 6 feet thick must be kept on the grate; and the height of the layer can be

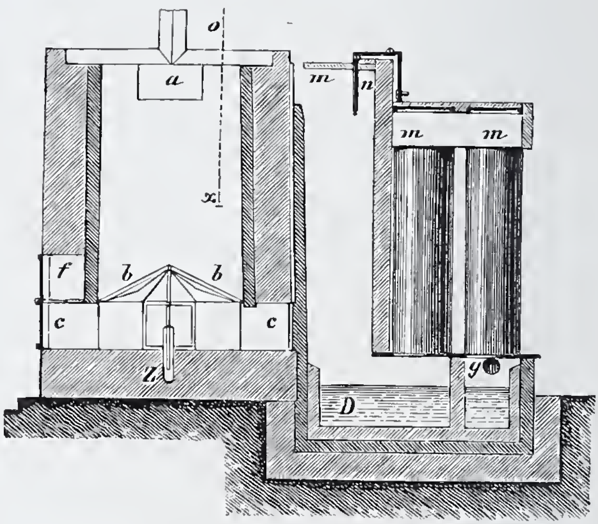

FIG. 12.—Sawdust Furnace for Gas Producers (Section through the Furnace and Condensers).

regulated by means of the rod, *o x*. The air-blast enters the furnace through a cast-iron pipe, *z*, which is covered with a cap to prevent the ash from falling into the air tube, and to subdivide the blast; above this is a pyramidal grate built up of eight segments, on which the fuel rests. For cleaning the grate there are four openings, *c*, *c*, at opposite points. The air pressure employed is generally three-quarters of an inch; for sawdust it should not exceed half an inch. The older patterns, which had

no grate, and in which the air-blast was introduced through three tuyères, did not prove satisfactory. The grate is now made of cast-iron; when sawdust is used alone the spaces between the upper edges of the fire bars should be about $\frac{5}{8}$ inch wide; for a mixture of sawdust and peat $1\frac{1}{4}$ inch; and for peat alone $1\frac{1}{2}$ inch. Above one of the openings, *c*, *c*, there is another opening which serves for withdrawing the fuel when the work is discontinued.

The openings are so constructed that the fire bars can be inserted or removed through them. It sometimes

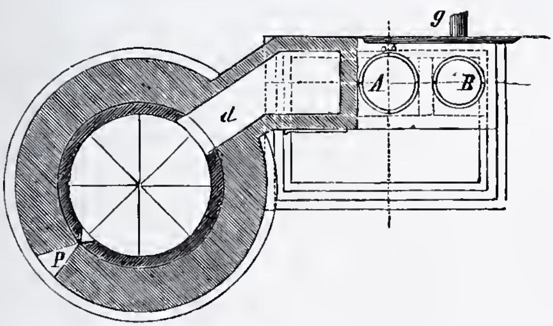

FIG. 13.—Sawdust Furnace for Gas Producers (Ground Plan of the Furnace and Condensers).

happens, especially when small peat is being used, that soot collects in the channel *d* which connects the producer with the condenser. For removing this soot an opening in the wall of the gas generator is provided. This opening is closed by a plate built into the brickwork, and pierced by a hole through which passes the shaft of a steel scraper, which fits the hole. The scraper, when not in use, is drawn back into a recess in the wall. Through *d* the gases pass to the condenser, A, B. This consists of two cylindrical vessels closed at both ends, and containing tubes through which the gases are conducted, whilst cold water, introduced at the bottom and allowed to flow out at

the top, circulates round them. The cylinders are constructed of sheet-iron, $\frac{1}{8}$ inch thick, the brass tubes are 9 feet 9 inches long and $1\frac{7}{8}$ inch in diameter. The water-supply pipe is $2\frac{3}{4}$ inches in diameter. Usually only one condenser is used for each producer. When the gases have passed through the condensers they are conducted by pipes to the furnace. The water and tar condensed from the gas collect in the tank, D, which is constructed of two thicknesses of slag-bricks and one of fire-bricks, with intermediate layers of a mixture of tar and cement. The tar flows over into storage vessels through the pipe *g*, whilst the water runs away by a gutter after it has been completely freed from tar by passing through a straw filter.

A producer consuming 620 bushels of sawdust daily yields about 440 gallons of gas-liquor. When the blast is on, the temperature of the gas increases considerably; and to protect the brass tubes a jet of water is introduced through the roof of the vertical channel which conveys the gas from the producer to the condensers. The water pipe is inserted through a hole in the valve, into which an iron plug is fitted. For distributing the water a baffle plate is fixed opposite the jet. The tubes in the condenser very rarely get choked; but if this should occur, the supply of cold water is diminished so that the gases may pass through the pipes warm, the stoppage being then soon cleared away. The apparatus is liable to the occurrence of small explosions, but these are generally occasioned by defective working of the producer. If the sawdust is too damp it often causes explosions; cavities are formed during the sinking of the charge, and in these air and gas become mixed. To provide against damage from these explosions, valves are placed in the roof opposite to the gas passage. These valves open when an explosion occurs and immediately close again. They are constructed

of cast-iron, and being so arranged that they cannot be lifted beyond a right angle, they therefore close again by their own weight. The air-supply pipe is fitted with a safety-valve, as close to the gas producer as possible, which, in the event of a stoppage of the blowing apparatus, closes the air pipe and prevents it from getting filled with the combustible gas. Such stoppages are very liable to occur from the driving-belt slipping off the pulley of the blowing apparatus. This valve consists of a wooden frame on which leather is stretched ; it is hung by a leather strap in a wooden valve-box, and the frame is so light that it is lifted by the air pressure: whereas, on the other hand, if a back pressure occurs, the frame falls and closes the air pipe. The top of the valve-box is formed of a stout sheet of paper glued down, and above this a wooden cover. These form a safety-valve in the event of gas obtaining admission to the tube between the producer and the valve. The combustible material employed in the producer may be sawdust, mixed with small coal, peat, etc. If it is desired to use a different material, it is only necessary to introduce suitable fire bars, and to increase the strength of the blast when the spaces between the bars are smaller. Each gas producer using sawdust yields $36\frac{1}{4}$ gallons of tar daily. A special arrangement is employed for collecting the gases from several producers in a single main. It consists, for each of the four producers, of rectangular cast-iron chests of different sizes. The medium-sized one receives the gases from the smaller ones and delivers them to the hydraulic main : all the small chests are fitted with conical valves.

The Lundin Furnace.

In this furnace an air-blast is used both to supply the air required for the combustion and to generate gas,

and a condenser is introduced to cool the gases and the water-vapour which they contain. The combustible gases generated in a gas producer fed with sawdust, and provided with an air-blast below the fire grate, are conveyed by a siphon tube into a box-shaped condenser, through the cover of which several fine jets of water are introduced. The jets of water impinge upon pointed pieces of metal placed opposite to the openings, and the water being thus scattered in all directions cools and condenses the vapours. In order that the condensation may be as perfect as possible, the gases, after leaving the condenser, pass upwards through a channel filled with iron lattice-work over which water is flowing, and thence into a valve-box from which they are distributed, through Siemens' regenerators, to the furnaces where they are to be used. When employed to heat puddling furnaces each hundredweight of bar iron consumes a quantity of sawdust equivalent to $\frac{3}{4}$ ton of wood-charcoal (2 tons of sawdust are equal to $\frac{4}{5}$ of a ton of wood-charcoal).

As the result of various trials the Lundin gas producer does not seem to be particularly advantageous to the iron manufacturer. This is due to the fact that a producer worked with a blast furnishes more carbon dioxide and less monoxide than one worked with a chimney draught, and that in the condenser, not merely water but also tar is condensed, which otherwise would have added to the heat effect. For the complete condensation of the tar very large quantities of water are required (8640 cubic feet in 24 hours).

It is only as a sawdust furnace that the Lundin apparatus has any value, this material being obtained in enormous quantities in Sweden.

The assertion that the system of condensing the tar (which would else have interfered with the working of the valves) has alone rendered the regenerative system pos-

sible in Sweden, is not correct, since regenerative furnaces constructed on other patterns are in full and constant work.

The introduction of water jets is a new and peculiar feature of the Lundin condenser. Whilst Lundin's apparatus is well adapted for the combustion of sawdust, it can only be expected to find very restricted use in countries where the same conditions do not obtain as in Sweden, since it would be only an expensive way of wasting such fuel as is of greater value.

From another source we have the following report :—

"The use of this furnace deserves to spread rapidly; it permits the direct use of undried, comminuted, and sulphurous fuel. It is very durable and leads to a considerable saving of fuel and diminished production of slag, good quality iron being also obtained.

"At Munksors in Warmland, a furnace worked with sawdust turns out 50 tons of iron in 6 days, with a consumption of 11 to 14 cubic feet of sawdust per cwt. of finished iron, and a loss of 11 to 12 per cent.: compared with former times, the output has doubled, the expenditure of fuel diminished by $\frac{1}{7}$, and the loss of iron by 1 per cent."

Godillot's Furnace with Pyramidal Grate for Pulverulent Fuel.

This furnace avoids the usual inconveniences of those fed with fuel, especially tan, sawdust, etc., through hoppers in the crown of the arch. The pulverulent material, falling on a horizontal grate, forms a heap which becomes consolidated by its own weight. In these circumstances the air penetrates with difficulty into the interior of the heap and the combustion is incomplete.

The system of pyramidal grates is applicable to all furnaces in which the fuel is introduced through hoppers.

The grate, which is of pyramidal form, is placed above the ordinary fire bars, and serves to support the pulverulent fuel which falls on the inclined faces from the charging hopper above. By this means a more uniform

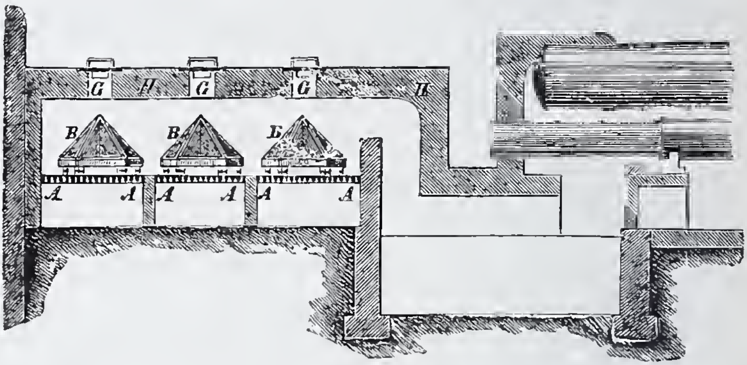

FIG. 14.—Godillot's Pyramidal Fire Grate (Longitudinal Section).

layer of fuel is formed, the air penetrates the whole mass more readily, and the combustion is greatly improved. Each of the charging orifices in the crown of the furnace is fitted with a pipe, which is somewhat contracted towards

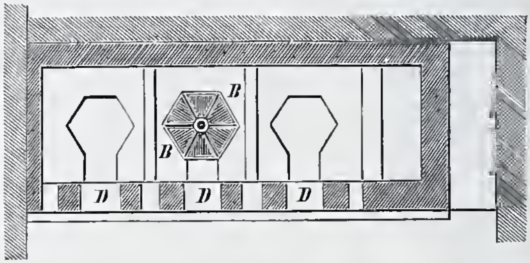

FIG. 15.—Godillot's Pyramidal Fire Grate (Horizontal Section).

the upper part. This pipe forms a sort of hopper, which gives a continuous, automatic feed to the fire grate.

The arrangement and mode of working the pyramidal grate are such that the stoker, without admitting cold air into the body of the furnace, is able to ascertain the state

of the fire, and to remove ash and clinker from the horizontal grate by means of a slicer.

Fig. 14 shows a longitudinal section, Fig. 15 a horizontal section, and Fig. 16 a transverse section of the furnace with the pyramidal grate; Fig. 17 the ground plan of one of the pyramids, and Fig. 18 a section of the same, as adapted to a furnace for burning tan, sawdust, etc.

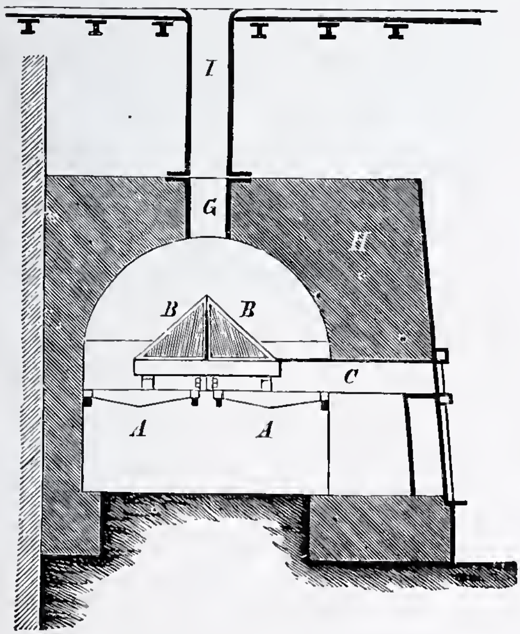

FIG. 16.—Godillot's Pyramidal Fire Grate (Transverse Section).

The horizontal grate is partly covered by the pyramid, which has a number of faces, B, B, B, each of them constituting an inclined grate. It is slightly elevated above the horizontal grate A, so that a poker can be inserted between the two for cleaning the fire bars.

For this purpose a cast-iron trunk C (Fig. 16) runs from the fire door D to the horizontal grate, in the form of a gutter. Underneath the pyramidal grate B and the gutter C

(the inner edge of which rests on same), the horizontal grate is solid, so that the ash collects thereon, below the grate, in the form of heaps. By this arrangement the fuel slides

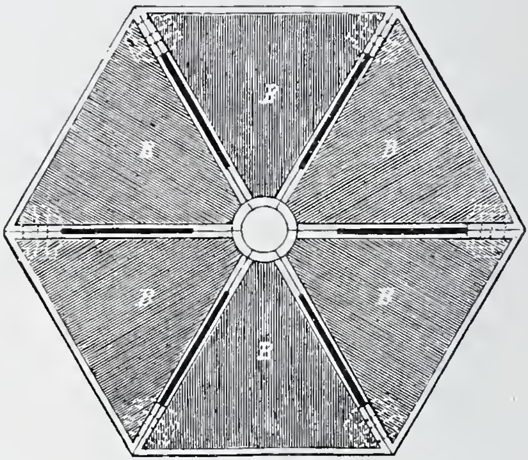

FIG. 17.—Plan of one of Godillot's Pyramidal Fire Grates.

down the inclined faces B, since these slope at a greater angle than the angle of repose of the material, that is to say, the inclination which the sides of a heap of the substance

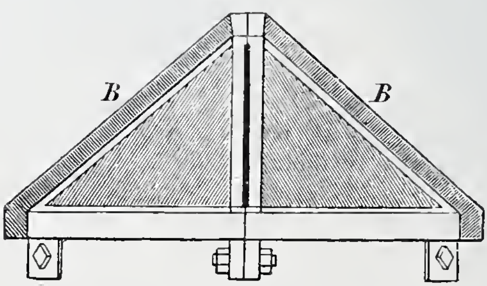

FIG. 18.—Section of one of Godillot's Fire Grates.

would naturally assume. It is therefore never necessary to clean the bars of the pyramidal grate B, the ash and clinker

collecting on the horizontal grate A. The pyramids may be constructed with a greater or smaller number of faces than are shown in Figs. 17 and 18. In these figures six faces are shown, each having the form of a triangle. The triangles are held together at their bases by screw bolts, but are loose at their apices, so that they may be able to expand. The faces may also be of trapezoid shape, and then form a truncated pyramid; or the grate may be conical and made in one piece. The form of the grate is to some extent dependent on the form and situation of the hoppers, which may be cylindrical, square, etc.

The dry or damp fuel is charged in through the openings G, G, in the crown, H, of the furnace (Fig. 14), but to produce an automatic and uninterrupted feed, a pipe, I, may be carried up from each of the openings, contracting somewhat towards the upper part, and serving as a store for fuel.

Swedish Wood-charcoal Furnace with Condenser.

The apparatus employed in Sweden for converting sawdust into wood-charcoal consists of rectangular chambers about 33 feet long and 21 feet 4 inches wide below, but narrowed to about 13 feet in width at the spring of the semicircular roof, and about $19\frac{1}{2}$ feet high. The side walls have a slight slope inwards. The bottom is flat except close to the side walls, where it slopes down to a cast-iron pipe which serves for carrying off the gases and condensable products. The former escape through a vertical tube of sheet brass, whilst the latter form a tarry deposit on the floor. A rectangular hearth, constructed of fire-bricks, covers half the width of the bottom of the chamber; this is in communication with five narrower pipes, which lead to the ends and sides of the chamber, and through which air is introduced. These

pipes rest on tapered iron supports about 9 inches high. The crown of the furnace is protected against rain by a light roof.

Sawdust and other waste from the saw-mills are brought by tram lines, and laid out to dry in the air until wanted for use. The charging takes place through doors, of which there is one at each end of the chamber. One of these doors, which is flush with the bottom of the chamber, measures 5 feet 9 inches by 4 feet 9 inches, the other is at the base of the arc and measures 59 by 39½ inches. The lower layer of the charge is formed of the larger waste pieces of wood for a height of about 1 foot; upon these the other materials are so placed that the length of the pieces runs parallel to the axis of the chamber. An experiment in which some of the layers were built up of pieces laid crosswise did not give a favourable result, but on the contrary occasioned a higher cost for labour.

As soon as the whole charge of wood, which amounts to 16,600 cubic feet, has been introduced, which can be done in 3 to 4 days by 10 men, the lower doors are closed and secured with bolts, and the fire is lit. The upper doors are left open until the third day, to furnish a free outlet for the water-vapour given off from the damp wood. A dark-coloured vapour is evolved up to the middle of the sixth day, after which it generally becomes bluish. The combustion is regulated according to the appearance of the vapour: should the combustion become too vigorous the pipes are partially closed, or the fire is damped in any convenient manner. In order to avoid exposing the structure to internal pressure by thus closing the outlets, the side walls are traversed near the upper part by narrow tubes which are left permanently open. According to the dryness of the wood, the carbonisation may take from 10 to 18 days; 16 days are required for cooling down, and the chamber can be emptied by two men in a day and

a half. After any needed repairs have been executed, a new charge is immediately introduced.

The annual output of one of these carbonisers amounts to 60,800 cubic feet of charcoal and 160 gallons of tar. The loss on carbonisation varies according to the dryness of the wood, and may on the average be put at 100 cubic feet, so that the quantity of the charcoal amounts to 6460 to 6840 cubic feet, from which it appears that the yield is 58 to 62 per cent. of the wood employed.*

The charcoal obtained from sawdust is less suitable for the blast furnace than for the refinery, especially when it is mixed with ordinary wood-charcoal. The carbonising chambers described above have the advantage, over the mounds or heaps covered with turf, extensively used in charcoal-producing districts, of a smaller cost for labour, and a cleaner charcoal; besides which the work is independent of the weather and requires less skill on the part of the workmen.

C. Walter's Sawdust Furnace for the Manufacture of Wood-tar.

One of the principal advantages of this furnace is that the grate can never become choked and cause irregular combustion; moreover, very fine sawdust can easily be burnt in this furnace without addition of any coarser material. It is used as a source of heat for a bench of two retorts. The fire is regulated by sliding dampers, and can be wholly shut off from either of the retorts, at will. The products are charcoal, tar, crude tar-oils, and calcium acetate. The retorts are set in pairs, and with a slight

* These percentages seem to be wrong, as the yields stated work out to about 38-42 per cent., assuming the loss of 100 cubic feet to be based on a charge of 16,600 cubic feet.

fall towards the rear. They have at the back two diametrically opposite holes. The lower hole is used both for rotating the (cylindrical) retort when its lower side is burnt out, and also for drawing off water in the early stages of the distillation, and pitch in the later stages;

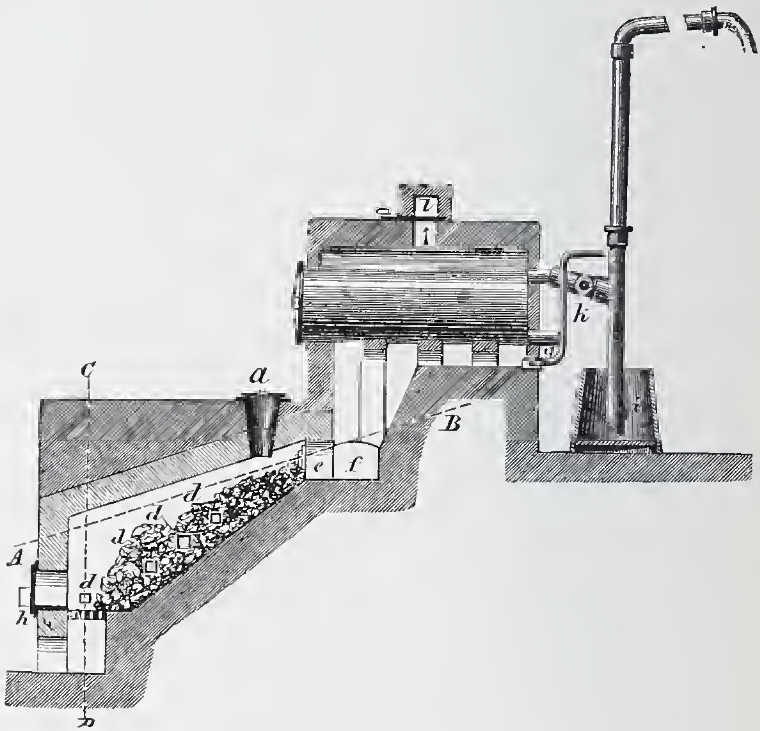

FIG. 19.—Walter's Sawdust Furnace and Stills (Vertical Section).

the upper hole serves for the escape of gases and vapours. Very wide tubes are employed for carrying off the products of distillation. They rise perpendicularly to a height of about 10 feet, and are then carried with a slope of about 10° to the condensing apparatus, which is placed at a distance of about 16 to 19 feet. As the vapours traverse

such a long course through these pipes, the more readily condensable vapours liquefy there and flow back towards the retorts, whilst only the acetic acid vapours, and the more volatile empyreumatic oils pass on to the condensers and are collected as pyroligneous acid and crude tar-oil. In this way two tarry products are obtained, a thick

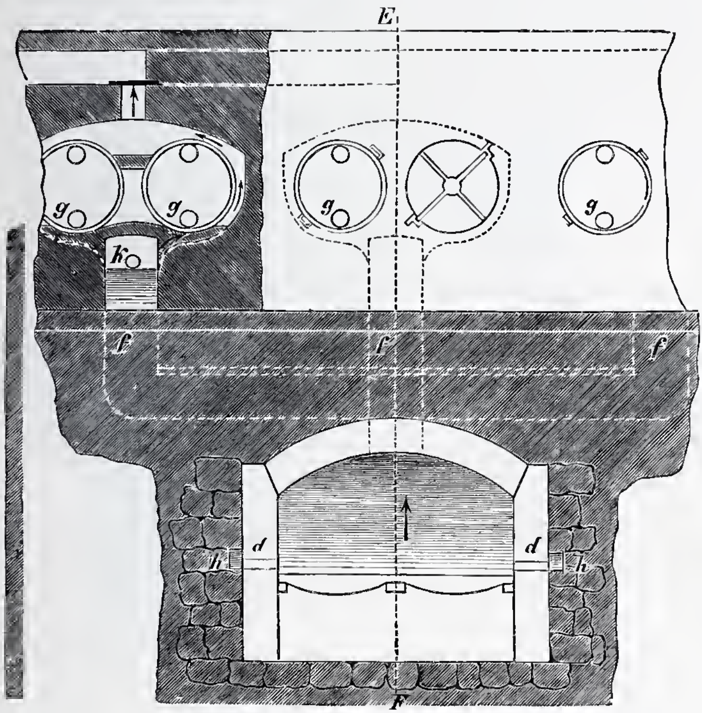

FIG. 20.—Walter's Sawdust Furnace (Vertical Section through the line C, D).

black tar, and a dark-coloured but fluid tar-oil resembling Finland tar in appearance, which is very much in demand for tarring ships, since it readily soaks into the wood and acts as a powerful preservative.

Fig. 19 shows a vertical section of the furnace through the line E, F, of Fig. 20; Fig. 20 a transverse section

through C, D, of Fig. 19, and Fig. 21 a section along the line A, B, of Fig. 19.

Through the charging hopper *a*, which opens above in the floor of the factory, so that the material can readily be brought to it, the sawdust is charged from time to time into the furnace, a fire having first been lighted with some other material. The sawdust slides gradually down the sloping floor of the fire chamber towards the grate *c* in

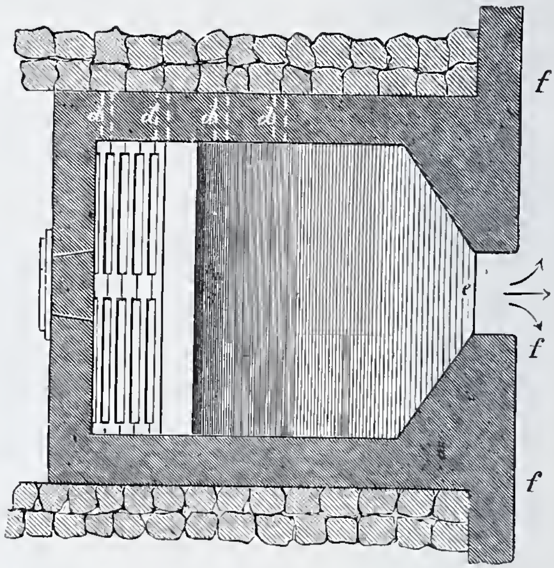

FIG. 21.—Walter's Sawdust Furnace (Oblique Section through the line A, B).

sufficient quantity to supply the place of that which burns away: the amount thrown into the chamber should never be so large that the grate becomes completely covered. The heap of sawdust burns at the surface, and all that is necessary is that from time to time a poker should be inserted through the door *h* to spread it about. If the grate should momentarily get choked (which, however, can only happen if too much sawdust has been thrown in) or if

it is desired to admit more air, the air channels, *d*, *d*, *d*, *d*, at both sides of the furnace, may be opened. The ash falls partly through the grate, partly also into the channels, *d*, *d*, which therefore must be so arranged as to be easily cleared. Through the neck *e* of the combustion chamber the flame passes into the flues, *f*, *f*, *f*, and is then distributed to the retorts. By means of dampers, *l*, *l*, *l* (Fig. 19), in the flues behind the retorts, the flame can be regulated or shut off from any of the pairs of retorts as required.

A chimney-stack with a good draught is essential. The permanent gas which is evolved from the retorts, together with the vapours of acetic acid and tar, is returned from the condenser to the fire by the pipe *k*, and contributes materially to the heating effect.

This sawdust furnace differs from others mainly in the fact that, with the exception of the small quantity lying on the grate, the heap of sawdust burns only at its upper surface, so that the obstructions which, in other forms of furnace, are caused by the subsidence of the mass of fuel with which the furnace is filled cannot occur here.

Furnace of Niederberger & Co. for Damp Waste-wood and Sawdust.

This furnace is designed for burning, without previous drying, the wet and finely subdivided wood-fibre which remains after the extraction of the dye from dye-woods. It is also well adapted for the utilisation of damp sawdust.

Fig. 22 shows the fireplace as arranged for heating a boiler. Fig. 23 is a transverse section along the line *a*, *b*.

The upper space, A, open at the top and enclosed by a wall, serves for the reception of the combustible material, which is constantly being thrown into it and piled up in a heap. In the floor of the enclosure, A, there is a row

of vertical apertures, B, B, B, under each of which an angle-iron girder, C, with a right-angled, or obtuse-angled edge placed upwards, is situated. The spaces between the lower edges of the girders are filled with fire bars, *e*, *e*, of the usual construction. The space H, below C and *e*, is

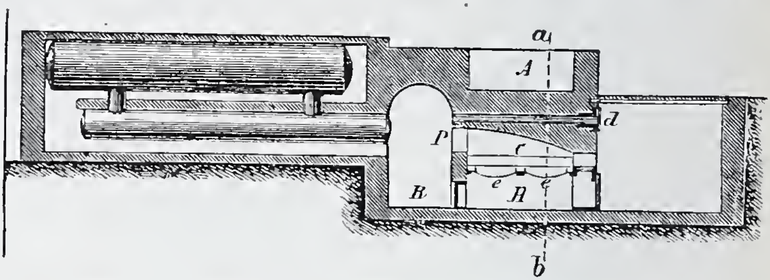

FIG. 22.—Niederberger's Furnace (Transverse Section).

the ash-pit. In front, before the ends of the fire bars, there are doors or valves, through which the lower layer of the refuse wood resting on C and *e* can be set on fire, the doors being tightly closed after this has been done. In the space above the grates an energetic evolution of gas and

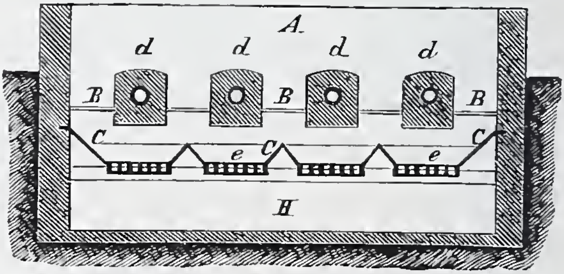

FIG. 23.—Niederberger's Furnace (Longitudinal Section).

smoke is produced from the combustible matter, which, as the lower layers burn away, sinks down on the sloping faces of the girders. The gases pass through the aperture, P, into the chamber, R, into which a separate supply of atmospheric air is admitted through tubes, *d*, which pass

through the brickwork forming the bottom of the enclosure, A, and which can be closed by either slides or valves so as to regulate the supply of air to the chamber, R. In this chamber the combustion of the gases takes place, and the flame is then conducted into the flues where its heating effect is to be utilised. The wood as it descends from the enclosure, A, dries completely before it reaches the grates, *e*, and is delivered regularly to the fire grates by the sloping surfaces of the girders, C, so that the fire requires no attention as long as a supply of wood is kept up in the enclosure, A.

Zwillinger's Apparatus for Carbonising Sawdust, etc., with Recovery of the Volatile Products.

The apparatus consists in general of a steam superheater (with the requisite boiler for producing the steam); of a cast-iron cylinder for the carbonisation of the material; of the ammonia apparatus, hydraulic main, cooler, and lead vessels; and of the apparatus for the illuminating gas, such as the gas purifier, holder, and tank. The carbonisation cylinder is filled from above from a charging reservoir of the same capacity, and is emptied below into sheet-iron vessels of similar size. The carbonisation is effected in the cylinder by means of superheated steam at 750° to 800° C.; whilst at the same time the cylinder is surrounded throughout its whole length by the waste flue gases from the superheater, before these pass off by the chimney. A furnace with four cylinders will require 35 lbs. of coal and 100 lbs. of steam per hour.

The superheated steam, which is admitted direct to the cylinders and passes thence through the hydraulic main and the cooler, raises the pressure in the cylinders and sweeps out the gases and vapours, through the sulphuric acid absorbers and gas purifiers, into the gas holders.

The working of the apparatus is free from danger, produces no nuisance, and is in the highest degree simple and convenient.

The wear of the gas and ammonia apparatus is so small that its durability for many years without repairs may be

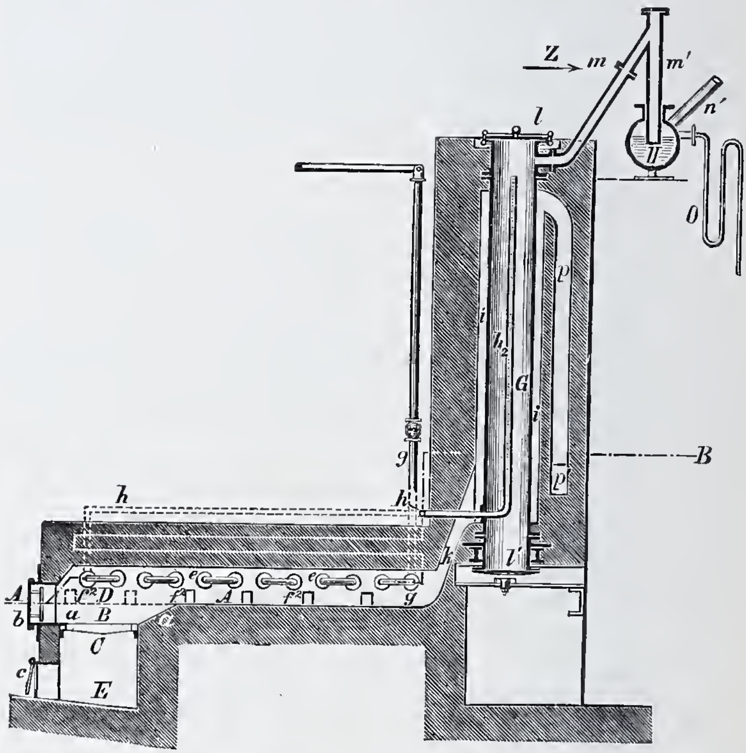

Fig. 24.—Zwillinger's Apparatus for Carbonising Sawdust (Vertical Longitudinal Section).

counted on with certainty. The carbonising cylinder and the superheater, when worked continuously, will run for at least three years without requiring any expenditure for repairs.

In order to maintain a uniform heat in the superheater furnace, and to ensure complete combustion of the fuel,

the fireplace is so built, by giving a batter to the side walls, *a*, *a*, lowering the fire bars, and introducing a vertical fire-brick partition wall, C, that two fireplaces, D, D, are formed, each of which is furnished with a fire-door, *b* (Figs. 24 and 25).

For regulating the air supply, each ash-pit, E, is fitted with an adjustable door, *c*.

In the superheating chamber, A, straight tubes, *e*, *e*, are supported on dwarf walls, *f*, *f*, and are connected by elbows, *d*, *d*, which project beyond the dwarf walls on

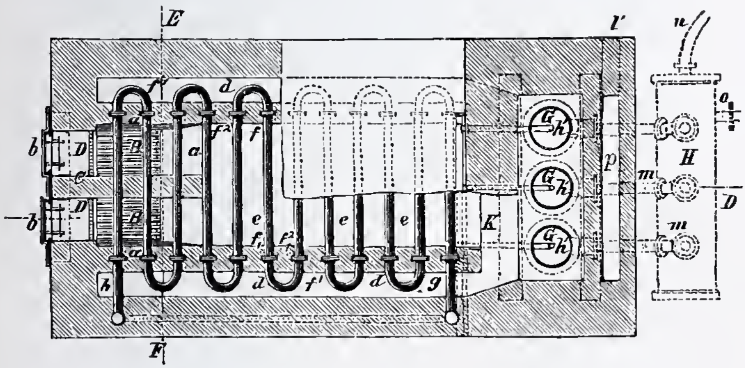

Fig. 25.—Zwillinger's Apparatus for Carbonising Sawdust (Horizontal Section).

both sides into narrow channels, *f′*, *g*, which communicate with the fireplace by pigeon-holes. The superheating chamber is not arched over, but covered with flat plates, which are supported by the walls, *f*, *f*. The steam enters at *g*, traverses the pipes, *e*, *e*, which are kept at a dark red heat, and is then carried by the pipe, *h*, in a highly superheated condition, to the carbonisers, G, G, G. The cylinder, G, which holds about 330 to 440 lbs. of the material to be carbonised, is constructed of cast-iron, and is furnished with covers, *l* and *l′*, at the top and bottom respectively, for charging and emptying. Each cylinder

contains a pipe (branching from the steam pipe, *h*) which is pierced with small holes throughout its entire length, and through which the superheated steam is passed into the substance to be carbonised. The carbonisation cylinders, which are most advantageously 12 inches in diameter, may either be placed vertically or horizontally, and are so set in the brickwork that a flue is left all round them, which communicates by pigeon-holes with the superheating furnace, A.

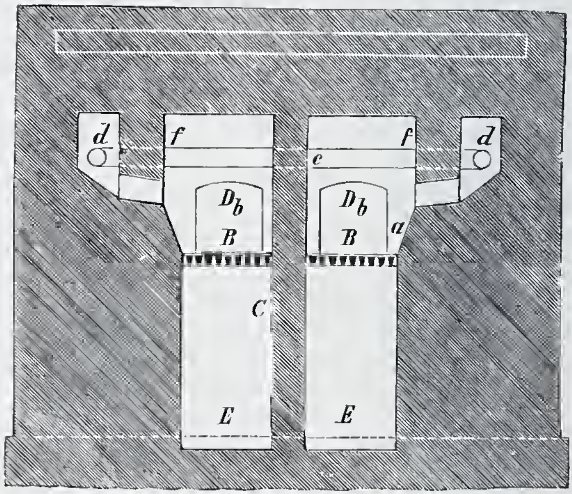

Fig. 26.—Zwillinger's Apparatus for Carbonising Sawdust (Transverse Section through the Superheater Furnace).

The heated gases issuing from the fireplace, D, are caused to pass through the superheating chamber, A, and through the channel, *k*, into the flue, *i*, which surrounds the cylinder, G, by which means the steam pipes, cylinder, and surrounding brickwork are all raised to a high temperature; the products of combustion then pass to the chimney by the flue, *p*, *p′*. The containing walls must be thick enough to prevent any material loss of heat by radiation,

and the heat of the gases is so far absorbed that they escape into the chimney at a temperature of about 160° C. The gases and vapours evolved during the carbonisation are carried by the pipe, *m*, *m′*, into a hydraulic main, H, from which they pass by the pipe, *n*, to the cooler. A syphon tube, O, branching off from the hydraulic main, keeps the ammonia * liquor in the main always at a constant level. To prevent the iron pipes of the superheating apparatus, and the cast-iron carbonisation cylinder from being burnt out by the oxygen in the hot gases, these are covered with a refractory lagging, which not only resists high temperatures but adheres firmly to the iron, and does not crack, melt, or peel off. This is composed of 100 parts of fire-clay, 20 parts of common clay, 40 parts of powdered bone-ash, and 2 parts of cow-hair or barley chaff. The fire-clay and the bone-ash must be dried and powdered, and then mixed with enough water to form a uniform plastic dough of the consistence of glazier's putty, into which the cow-hair or the barley chaff is then thoroughly kneaded. With this composition the superheater tubes are covered to the thickness of about ½ an inch, and the carbonisation cylinder with 1⅛ inch. They are allowed to dry for 24 hours, and may then, at once and without risk, be exposed to a red heat of 1000° C. Carbonisation apparatus, similar to the above, may advantageously be used for the production of coal gas with recovery of the by-products.

The carbonisation apparatus serves for the production of charcoal from the waste materials mentioned above, and for the recovery of the products of distillation, such being sulphate of ammonia, pyroligneous acid, acetate of

* There seems to be some confusion of thought here; the distillation of wood yields but little ammonia, the chief product, besides tar, being acetic acid.—(TRANS.)

lime, acetic acid, illuminating gas, tar, *Oleum cornu cervi*, etc.; it can be employed for the utilisation of exhausted dye-woods, tan, sawdust, fir cones, horse chestnuts, fruit stones, nut and almond shells, etc., and effects the carbonisation with superheated steam at a temperature of 750 to 800° C.

The yield obtained from 100 parts of sawdust, exhausted dye-wood, or spent tan, is as follows:—

Charcoal	21	to	23	per cent.
Tar	7·9	,,	8·6	,, ,,
Pyroligneous acid (5 per cent. of wood-spirit and 6 per cent. of acetic acid)	35	,,	45	,, ,,
Gas	20	,,	23	,, ,,

This is equivalent to 1400 cubic feet from each charge of 2 cwt., requiring 60 to 65 minutes to distil.

The tar obtained by distillation with superheated steam is especially distinguished by the fact that the tar oils obtained from it are particularly easy to purify, and yield very pure products. Moreover, this method of carbonisation gives a larger yield than was the case with any carbonisation furnace previously in use.

The gas may either be employed for illumination, or, where there is no demand for such, may be used for raising steam in the boiler.

Fischer's Apparatus for Carbonising Wood with Recovery of the Volatile Products.

This apparatus, shown in Fig. 27, consists of three superposed portions, namely, two vessels set in brickwork, and a removable reservoir, which is omitted in the figure. These three vessels, which can be closed air-tight, are connected with one another by several tubes, provided with stop-

cocks. Each vessel is furnished with a stirrer and a thermometer. The upper vessel ("Drier") is fitted with

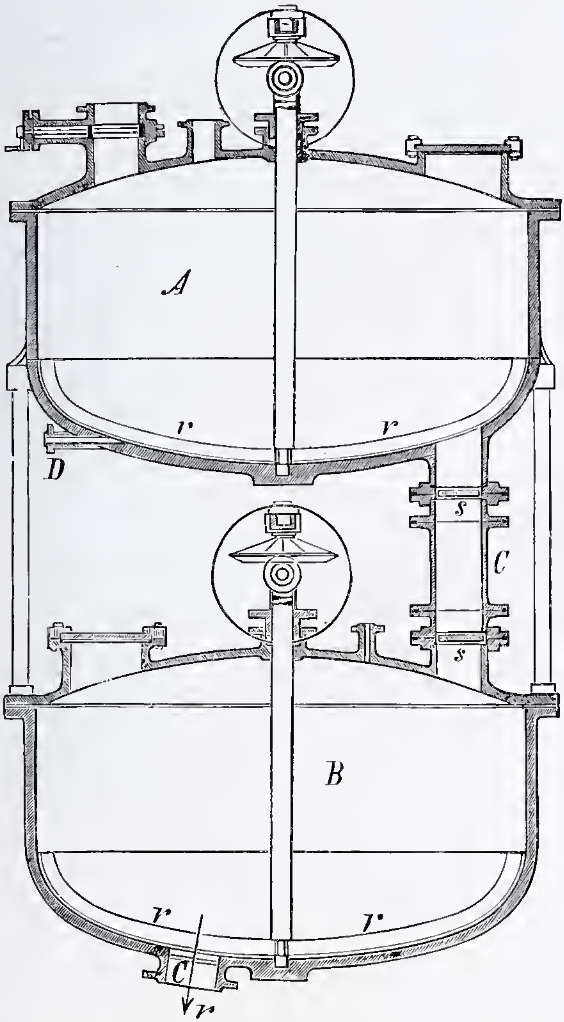

FIG. 27.—Fischer's Apparatus for Carbonising Wood.

a supply pipe for the admission of steam superheated by waste heat, or else of dry warm air; the lower vessel ("The

Carboniser") is in communication with a vacuum pump. The tubes which carry off the gas and volatile products from both vessels are closed at their outer ends by hydraulic seals, and at their inner ends with arrangements for arresting dust. The "Drier" is kept at as constant a temperature as possible, by the waste heat from the lower vessel, as well as by the combustion of the uncondensable gases obtained during the carbonisation. The "Carboniser" is heated by a direct fire or by producer-gas.

The material to be carbonised is fed into the "Drier," the stirrer of which is kept in motion, and in which a constant temperature of about 130° C. is maintained, whilst dry steam or heated air is blown in. By their direct contact with the wood a rapid drying, and at the same time a disintegration of the wood are caused. When the drying is complete the contents of the vessel are transferred by the stirrer to the "Carboniser," by opening the valve between the two vessels. The stirrer of the lower vessel is kept running; the temperature at the time of filling will be about 150° C. As soon as the upper vessel is empty, the valve communicating with the lower is closed, and the chamber is recharged, whilst the lower vessel is now heated to the carbonisation temperature at such a rate as gives the largest yield of crude acetic acid and the smallest proportion of uncondensable gases. Whilst the "Carboniser" is being raised from 150° to the carbonising temperature, it is evacuated as completely as possible by the attached air pump, after which dry steam, or an inert gas, is admitted in place of air until the pressure in the vessel is again equal to that of the external atmosphere. The carbonisation then goes on out of contact with air, so that combustion of the gaseous products of distillation is rendered impossible. The result is a higher yield, especially of wood-spirit (methyl alcohol), than is the case with earlier carbonisers. The volatile products are drawn

over into a cooler. When the carbonisation is complete the stirrer is stopped, and the vessel and its contents are allowed to cool down to about 150°, whereupon the granular wood-charcoal is discharged by the stirrer into a receptacle in which it is allowed to get completely cold out of contact with air. The "Carboniser" is then filled afresh.

Halliday's Apparatus for the Production of Pyroligneous Acid.

The apparatus constructed by Halliday is a continuous one, and consists of a cylinder with a feeding screw. According to the speed with which the screw is driven, the wood

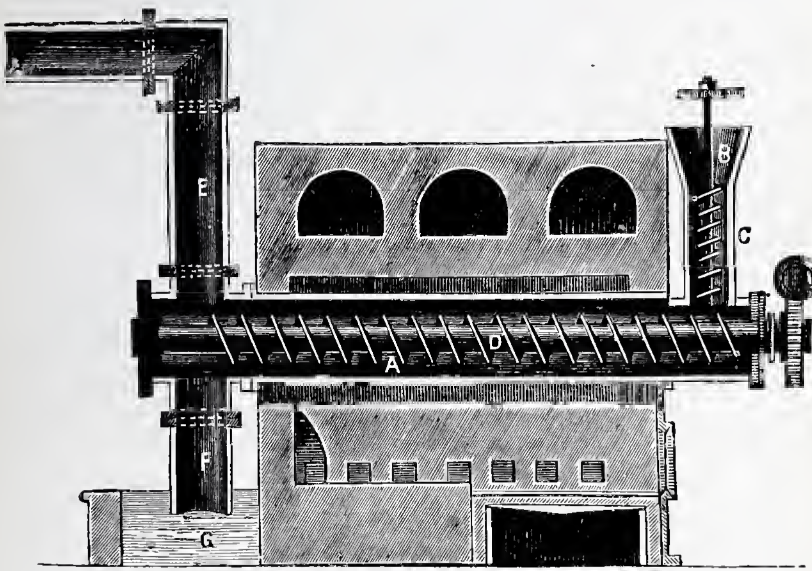

Fig. 28.—Halliday's Carbonisation Apparatus.

can be exposed for a longer or shorter time to the action of the heat, and thus a larger yield of acetic acid is obtained than is possible in the case of charcoal heaps. This

fact is, however, not attributable to any especially favourable construction of the apparatus, but exclusively to the form of the raw material. From small fragments of wood the distillate is much more rapidly evolved than from large billets, and the distillate undergoes less decomposition in the apparatus. 2 cwt. of sawdust yield from 10 to 12 gallons of a liquid containing 4 per cent. of acetic acid, besides $1\frac{1}{4}$ to $1\frac{3}{4}$ gallons of tar.

The sawdust is thrown into the hopper, B (Fig. 28).

In this hopper a revolving screw, C, delivers the material at an appropriate rate into the horizontal cylinder. The latter is heated by the furnace, A. A second screw, D, keeps the material in the retort in constant motion, and at the same time conveys it gradually to the other end of the cylinder. The wood becomes carbonised as it traverses the cylinder, so that by the time it reaches the farther end it has parted with all its volatile products. Two pipes are connected with this end of the cylinder. One of these, F, descends into an air-tight closed cast-iron receiver, or else into a cistern, G, filled with water; the other, E, carries off the products of distillation to the condenser, which consists of tubes surrounded with cold water. Some dye-wood grinders convert all their waste wood into acetic acid in this manner, with great advantage to themselves. The yield of acid is almost as large as would be obtained from the original wood by the ordinary methods.

Columnar Distillation Apparatus.

This apparatus, which is also especially suited for sawdust, dye-wood, wood-refuse, and tan, consists of a vertical sheet-iron cylinder about $17\frac{1}{4}$ feet high and $5\frac{1}{4}$ feet in diameter, and contains a number of superposed bell-shaped rings, each about 4 to 9 inches high, thus forming a kind of annulated cylinder, the lower end of which has the form of an inverted cone.

The wood-refuse charged in at the top is heated in the annulated cylinder, and the evolved vapours rise into the

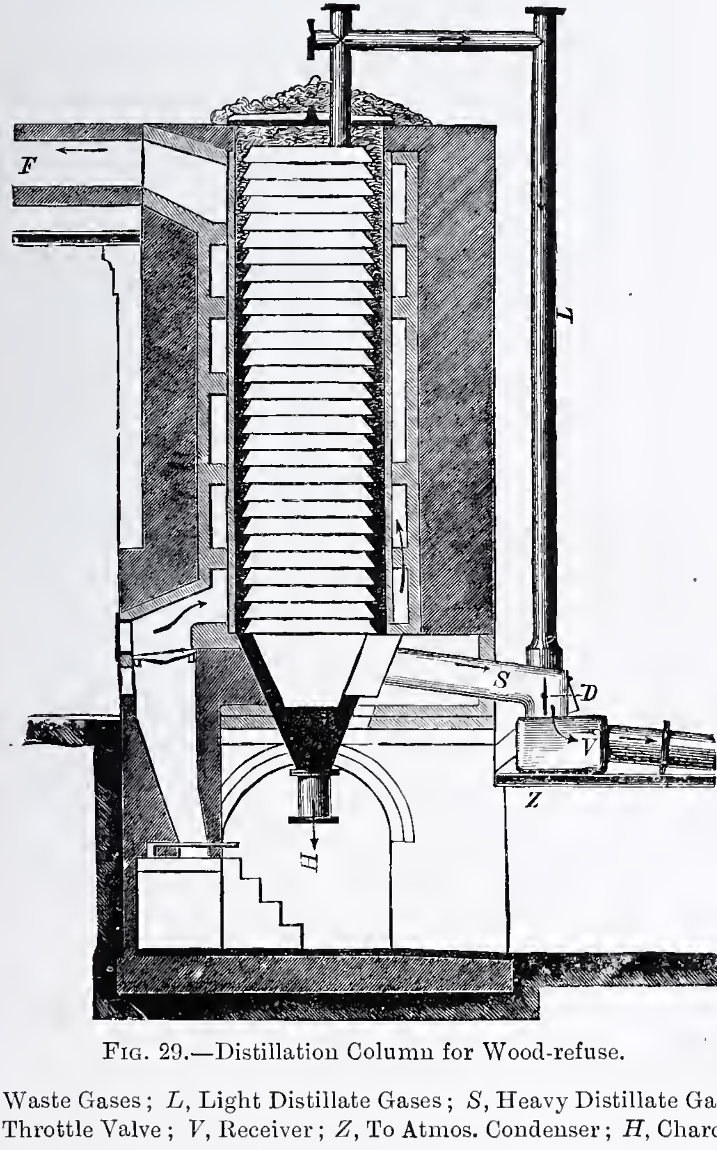

FIG. 29.—Distillation Column for Wood-refuse.

F, Waste Gases; *L*, Light Distillate Gases; *S*, Heavy Distillate Gases; *D*, Throttle Valve; *V*, Receiver; *Z*, To Atmos. Condenser; *H*, Charcoal.

inverted bells, whilst the charcoal is removed at intervals from the bottom. As the lower part of the cylinder can be closed by a valve, the distillation can be carried on, without intermission, by continuously charging the wood in at the upper end. The small charcoal obtained from the distillation of wood-refuse may be made use of in various ways; one part is burnt on suitable grates (step grates) to furnish heat in the factory itself; the remainder, especially when sawdust is carbonised, forms, in the finely divided condition in which it is obtained, a very serviceable disinfectant; in Vienna, where charcoal has a high value as a fuel, it is well adapted for the manufacture of briquettes.

Waisbein's Distillation Apparatus with Producer-Gas.

Waisbein made experiments on the application of producer-gas to the dry distillation of wood. The gas was generated in the furnace, A, by the combustion of wood-charcoal, and was drawn by the ventilating fan, B, which was set in motion by water power, through the retort, C, containing the material to be distilled. The operation was carried on in the following manner: After the retort was charged, the valve, D, and the tap, E (the latter of which supplied water to the fan), were opened as far as was necessary to bring the temperature of the entering gases to 150°, the temperature being observed by the thermometer, *t*. The hot gases traversed the retort, and arrived at the condensing coil, K, loaded with water-vapour. In the coil the water-vapour was condensed, and flowed through the collector, M, into the receiver, N; the cooled gases were drawn off by the fan. After the wood had become dry, the valve, D, and the tap, E, were further opened, so that the gas reached the retort at a temperature of 280°, and the oxygen compounds were collected

separately. The valve, D, and the tap, E, were then fully opened; the temperature of the gases rose to 430° C., at which temperature the tar distilled over. The products from birch-wood containing 15 per cent. of hygroscopic moisture were

27 per cent. of water;
27 ,, ,, of pyroligneous acid, containing 21·8 per cent. of acetic acid;
1·2 ,, ,, of wood-spirit;
31 ,, ,, of charcoal.

Pine-wood yielded approximately the same proportions, but the pyroligneous acid contained only 12·9 per cent. of acetic acid.

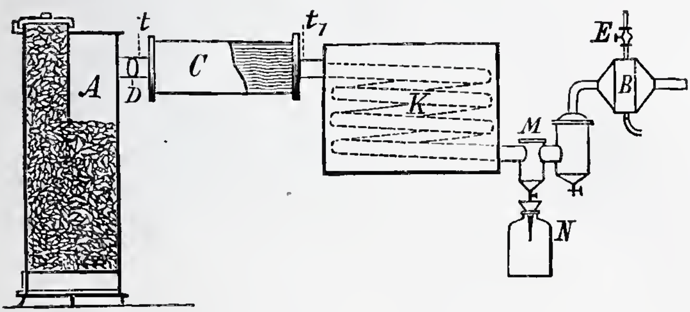

FIG. 30.—Waisbein's Experimental Apparatus.

In consequence of these results an experimental plant was constructed. In Figs. 31 to 34, A is the gas producer: the fuel is introduced through the doors at the top, through which also enters the air necessary for the combustion. B is the chimney, which, however, is only used when lighting the fire, and is shut off by the slide valve, *a*, before beginning the distillation. C is the tube which conveys the gas from the producer to the retorts, D, D. The gases and volatile products issue from the retorts by the tube, K or Z, according to whether the valves, *i* or *u*, are opened. The hot gases, together with the gaseous pro-

ducts of distillation, carried off by the tube, Z, enter the cooler, N. Here the products of distillation condense and flow into the receiver, M, whilst the gases pass into the vessel, P, and from thence are pumped out by a Körting's injector, which is employed to produce the draught through the whole system.

The temperature of the gases entering and leaving the retorts was indicated by the thermometers, *t*, *t'*. It appeared at the outset that certain errors in the planning of the apparatus had been made. It was discovered (1) that the

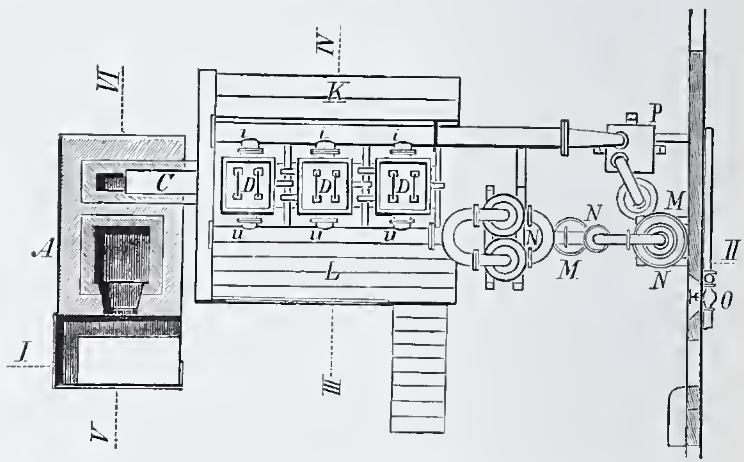

FIG. 31.—Waisbein's Distillation Apparatus (Ground Plan).

temperature of the producer-gas where it entered the retorts was too high; (2) that the cooling surface of the condenser was too small, so that the products of distillation could not be sufficiently cooled. Moreover, the sectional form of the retorts was not the most suitable. In consequence of the disadvantages thus introduced into the operation, the temperature of the gas which entered the retorts could not be controlled as completely as was desirable. When a temperature of 280° was required the screw valve, *g*, could only be opened a very little way (5 turns out

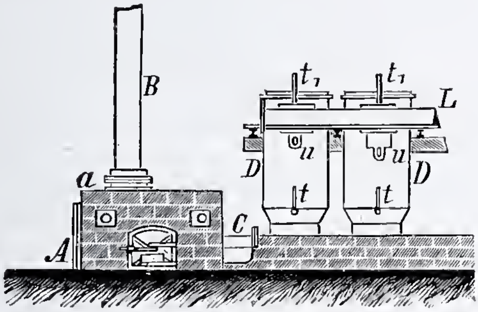

FIG. 32.—Waisbein's Distillation Apparatus (Section through I., II.).

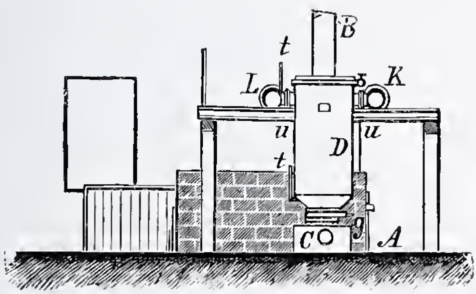

FIG. 33.—Waisbein's Distillation Apparatus (Section through III., IV.).

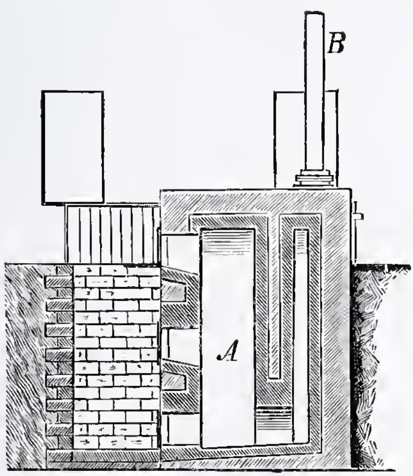

FIG. 34.—Waisbein's Distillation Apparatus (Section through V., VI.).

of 35), and the distillation then occupied an unreasonably long time. If the valve was fully opened the distillation was finished in 45 to 55 minutes, but the temperature rose far above 280°, and the resulting distillate was then contaminated with tar.

The yield obtained in the distillation of birch-wood amounted to 95·5 per cent. of the theoretical yield.

Petri's Apparatus for the Manufacture of Prepared Fuel.

The portable apparatus constructed by Petri was designed with the object of burning a pulverulent or granular fuel by submitting part of it, which was used for kindling the fire, to a preliminary preparation. This treatment is of such a character that the combustible substance can be instantaneously brought, by means of a small flame, into a condition of vigorous combustion, which is then transmitted to the whole mass.

The composition of the powder is such that it absorbs the condensable and combustible vapours given off by heating the fuel. When the fuel has been sufficiently heated, and has given up part of its combustible vapour to the powder, becoming at the same time porous, the latter has undergone the necessary "preparation," and can be removed to the combustion chamber and set on fire. The powder then readily gives up the vapour of all the volatile hydrocarbons which it has absorbed; these take fire, and by this means the whole of the prepared material is gradually brought into a state of combustion, the porous condition of the heated wood assisting the action of the atmospheric oxygen.

The powder consists of dry sawdust, or some other finely subdivided organic substance such as peat dust, with which finely powdered colophony, or some other readily combus-

tible resin, has been mixed. The quantity of colophony added is regulated according to the proportion of volatile constituents already contained in the fuel, resinous fuels such as sawdust requiring a very small amount, coal a larger quantity, and peat and coke the largest of all. The apparatus for heating the kindling material may either be connected directly with the combustion chamber, so that the material which has undergone the necessary prepara-

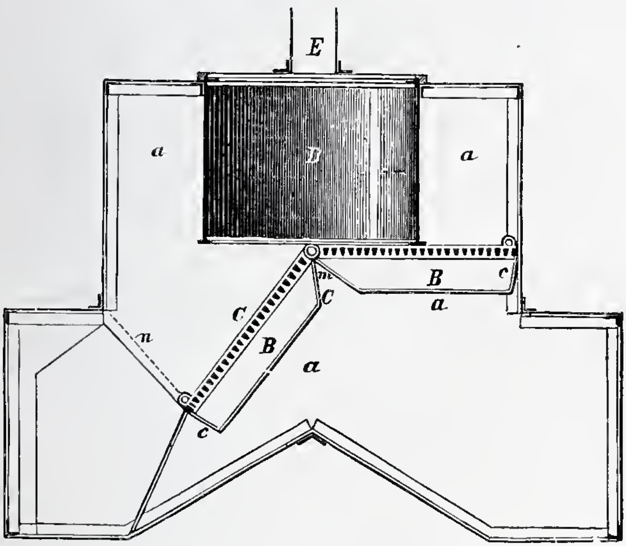

FIG. 35.—Petri's Combustion Apparatus.

tion may be directly transferred to the fire grate, or it may be entirely separate.

The figures show two forms of the apparatus for the separate preparation of the material (Figs. 35 to 41). Those forms in which the combustion chamber is connected with the heating apparatus, operate in exactly the same manner as those we are now considering. In the apparatus shown in Figures 35, 36, 37 (Figs. 38 and 39 show a portable apparatus of the same character for locomotives) the fuel

is introduced, in admixture with the powder, into the space, *a*. The bottom of this space is formed of two four-sided hollow

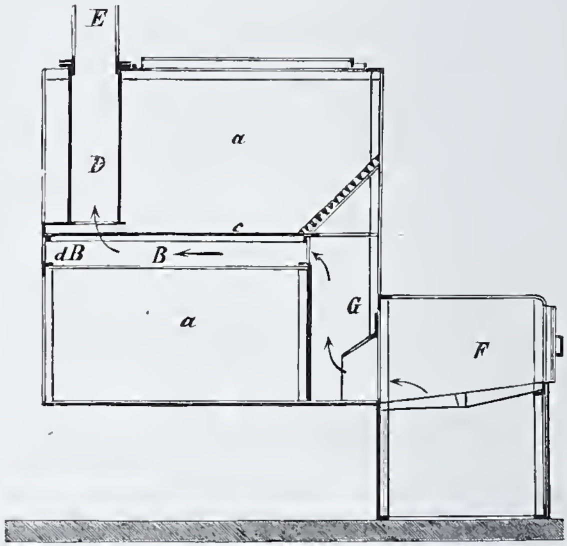

Fig. 36.—Petri's Combustion Apparatus (Transverse Section).

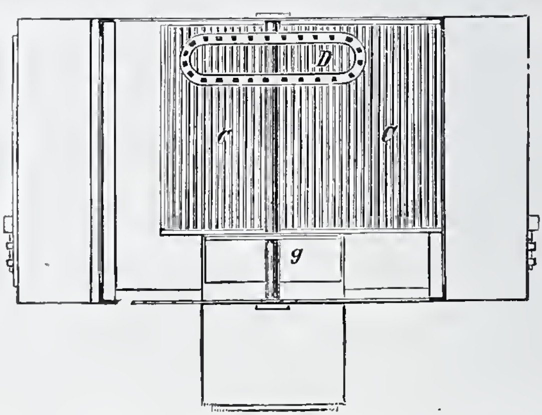

Fig. 37.—Petri's Combustion Apparatus (Ground Plan).

prisms, B, open at one side, the prismatic faces, *b*, *c*, *d*, and the base, *a*, being constructed of sheet-iron, whilst the fourth prismatic face consists of a fire grate, C.

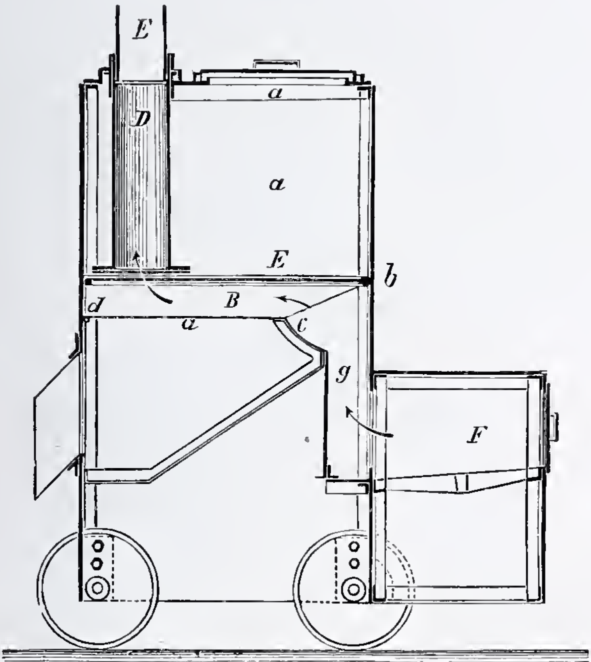

FIG. 38.—Petri's Portable Combustion Apparatus (Transverse Section).

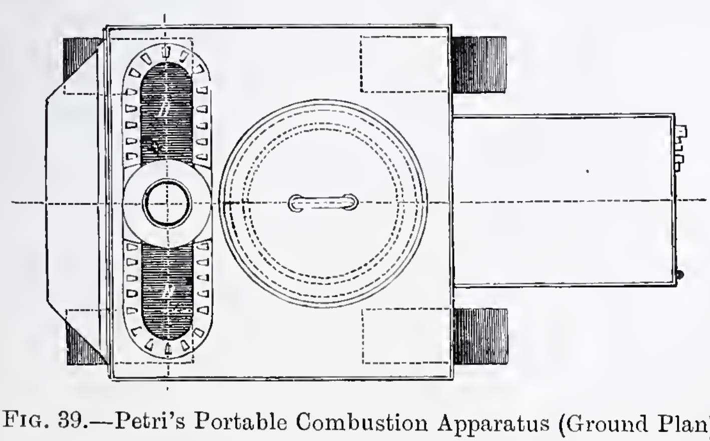

FIG. 39.—Petri's Portable Combustion Apparatus (Ground Plan).

The prisms, B, can be rotated on a pivot, *m*, and can be kept in a horizontal position by the pulley, *n*. Connected with these two prisms is a vertical chamber, D, the walls of which are constructed of grate bars, and which opens above into the chimney. The fire which heats up the materials is lit in the chamber, F. The fire gases pass

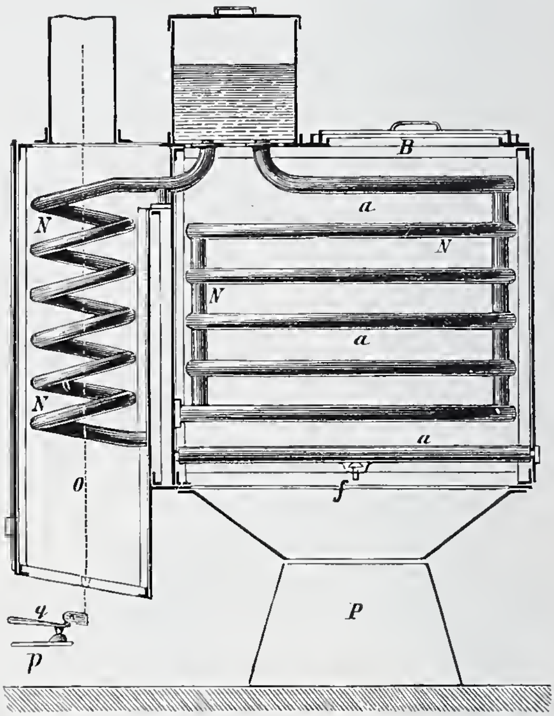

Fig. 40.—Stationary Combustion Apparatus of Petri (Modification).

through the chamber, D, parting with their heat on the way. When the material has been suitably prepared, that is to say, heated up, the chains, *n*, are released and the prepared material falls into cases, which are then transferred to the combustion chamber, emptied out upon the fire grate, and their contents set on fire. The forms shown in

Figs. 38 and 39 can also be adapted to locomotives. In this event the material falls directly into the fire-box of the locomotive.

The apparatus shown in Figs. 40 and 41 consists of the fuel chamber, *a*, containing a coil filled with calcium chloride, and a copper tube, N, heated from the combustion chamber, O. The circulating liquid gives up its heat to the mixture of fuel and powder.

After sufficient warming the valve, *g*, is opened by the rod, *p*, and the prepared material falls into the cases, P.

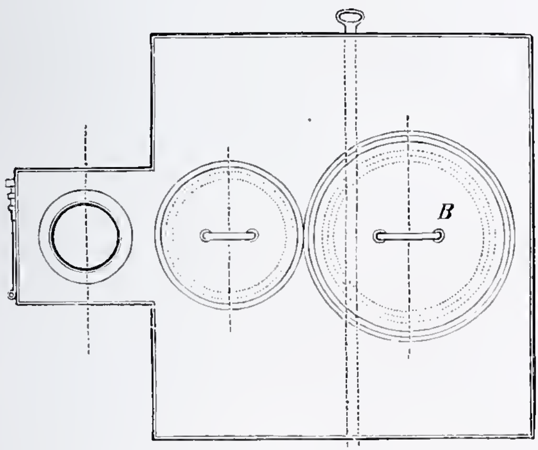

FIG. 41.—Stationary Combustion Apparatus of Petri (Modification).

This apparatus is more expensive to construct than that first described, but affords a more uniform warming of the material and an accurate control of the temperature by means of a thermometer dipping into the calcium chloride solution.

MANUFACTURE OF ILLUMINATING GAS FROM SAWDUST.

The production of illuminating gas from wood is a process of dry distillation; as we have seen, this process yields acetic acid, tar, and charcoal, together

with gases which consist of carbon dioxide and monoxide, but possess little illuminating power if the distillation is carried on slowly. If, on the contrary, wood is rapidly heated to a high temperature, the greater part of the volatile products undergoes decomposition, and hydrocarbons are formed which are partly liquid and partly gaseous. By rapid distillation wood yields large volumes of gas, which is easily purified, and possesses very considerable illuminating power; charcoal, tar, and small amounts of acetic acid being obtained as subsidiary products. The retorts are similar to those used for the distillation of coal; they must be filled with wood (sawdust, refuse, etc.) only to one-third of their capacity. The retorts should be at a full red-heat before the wood is charged in, and the charging must be performed as rapidly as possible, large volumes of gas being evolved at an early stage of the distillation. The time required for working off a charge is 75 to 120 minutes. In consequence of the rapid decomposition of the wood a certain amount of pressure is developed in the retorts, which, however, is rather an advantage as it keeps the tar-vapours somewhat longer in contact with the hot walls of the retorts and promotes their decomposition. In the gas works of H. Walker at Deseronto (Ontario) illuminating gas has for some time been manufactured from sawdust, and similar wood-gas plant is at work in other localities, and is employed for illuminating the workshops. As raw material, well dried pine-wood sawdust is used, which yields 20,000 to 30,000 cubic feet of gas per ton. The retorts used are similar to those ordinarily employed for making coal gas; the process of purification is, however, different, since the impurities in wood-gas are different from those obtained from coal. Sulphuretted hydrogen and ammonia, which are the chief troubles of the coal-gas manufacturer, are almost entirely absent from wood-gas. Resinous wood is, of course, pre-

ferred to other woods for the manufacture of wood-gas, as it not only gives a larger volume, but yields gas of higher illuminating power. In the works mentioned above, the drying of the sawdust, which is one of the most essential conditions of a well-organised gasification, as well as the other preparation of the raw material, is carried out almost entirely by mechanical appliances. In localities where sawdust can be cheaply obtained, and where there is a demand for the by-products, such as charcoal, wood-tar, wood-vinegar, etc., the manufacture of wood gas is able to compete advantageously with that of coal gas.

The crude wood-gas contains very considerable amounts of carbon dioxide, which it is necessary to remove, since the presence of this dioxide markedly diminishes the illuminating power of the gas. Since this, however, can only be effected by the use of lime, and since 1000 cubic feet of gas require 66 to 77 lbs. of lime, the cost of the gas is materially enhanced. The lime in the purifiers combines also with the creosote, and with any acetic acid which has not been condensed in the coolers. The amount of creosote absorbed is only small, since its compound with lime is decomposed by carbonic acid.

Two cwt. of wood yield—

1200 to 1400 cubic feet of gas ;
1 to $1\frac{3}{4}$ lb. of pyroligneous acid ;
$4\frac{1}{2}$ lb. of tar ;
33 to 44 lb. of charcoal.

CHAPTER III.

MANUFACTURE OF OXALIC ACID FROM SAWDUST.

This technically important substance was first obtained in 1773 from salt of sorrel (acid potassium oxalate) by Savary. Oxalic acid does not seem to exist in the free state in nature, but occurs in combination with potash as acid potassium oxalate, and in combination with lime as calcium oxalate.

At one time oxalic acid was manufactured by the very costly process of oxidising sugar with nitric acid, but at present it is made from cheaper organic substances without using nitric acid. Among these organic substances sawdust is the most important, in consequence of the abundance of the supply and the low cost of this material.

1. Soda Lye Process.

To prepare oxalic acid, 30 to 40 parts of sawdust are mixed with soda lye of specific gravity 1·35, containing 100 parts of actual alkali, and the mixture is heated in shallow pans to evaporate the water. The temperature to be employed is variously stated as from 175 to 240° C., but the higher of these temperatures should not be exceeded, as the oxalate of soda would be decomposed into carbonate. As soon as particles of wood can no longer be seen in the mass, the fusion process may be considered finished, and the mixture is allowed to cool. The product contains sodium oxalate and carbonate, together with substances of the nature of humus, and the excess of the alkali origin-

ally employed. The mass is lixiviated with the smallest possible quantity of cold water, taking care that the solutions which are run off are not weaker than 35° Bé. By this operation the more readily soluble salts are dissolved, whilst the sodium oxalate is left as residue. Another method is to dissolve the mass completely in the smallest possible quantity of boiling water, dilute the solution to 38° Bé., and allow to cool. Sodium oxalate crystallises out, and can be freed from the mother liquor by a centrifugal hydro-extractor.

The crystallised sodium oxalate is redissolved in boiling water and mixed with milk of lime in an iron vessel which is fitted with a mechanical stirrer. By this means it is converted into calcium oxalate and sodium hydroxide (caustic soda). To avoid an injurious excess of lime, the amount of quicklime for each operation is calculated and slaked. The greater part is added slowly to the boiling solution of the sodium oxalate; and, during the addition of the remainder, samples are tested at short intervals by filtering, supersaturating with acetic acid and adding calcium chloride. As long as this produces a precipitate or turbidity, indicating that sodium oxalate is still present, the addition of the milk of lime is continued. The precipitate of calcium oxalate is then allowed to subside, and the supernatant soda lye is drawn off and used for another melt, so that no waste of the caustic alkali takes place. The calcium oxalate is repeatedly washed with water; and the washings may be concentrated to recover the contained alkali or may be used for lixiviating. The calcium oxalate has now to be decomposed, for which purpose it is mixed with water to the consistence of a thin pulp, heated by steam in a lead-lined vessel, and treated with sulphuric acid (15 to 20° Bé.), steam being meanwhile passed through the liquid until it boils. The amount of sulphuric acid to be used depends upon the amount of lime which has been

required for decomposing the sodium oxalate, 56 parts of quicklime (calcium oxide) requiring 98 parts of sulphuric acid (H_2SO_4) for conversion into calcium sulphate. If to 1 part of lime there be taken 2 parts of sulphuric acid (66° Bé.), or an equivalent quantity of a weaker acid, this will give an excess which will advantageously assist the decomposition. The oxalic acid solution is now decanted from the precipitated calcium sulphate, the precipitate is repeatedly stirred up with water and finally is passed through a filter or filter press to recover the adhering solution. A sample of the precipitate is thoroughly washed with water, treated again with sulphuric acid, and tested with potassium permanganate for oxalic acid. If the warm solution decolorises the permanganate, oxalic acid is still present, and the precipitate requires a further treatment with sulphuric acid. The solution of oxalic acid is evaporated in a shallow lead pan. When the liquid reaches a specific gravity of 15° Bé. the evaporation is stopped, and the liquid is left to cool in order to allow the calcium sulphate, which was present in the weak solution, to settle down. The liquid, separated from the precipitate, is further concentrated in a second pan to about 30° Bé., and then run into shallow lead-lined wooden crystallisers. The degrees of concentration here mentioned must only be regarded as approximate, as they require to be modified according to the temperature of the room in which the crystallisation is to take place. Thus, in winter the first concentration must be stopped at 10° Bé., otherwise oxalic acid would crystallise along with the calcium sulphate.

The mother liquor is separated from the crystals by a centrifugal machine; it contains sulphuric acid, and can be employed in the next decomposition of calcium oxalate. The remainder of the mother liquor is removed by dissolving the crystals in a little boiling water and recrystallising.

Considering the relatively high cost of the alkali used, it is important to use the caustic lyes repeatedly; they are, however, highly contaminated with organic matter, from which they must be freed by evaporation and calcination. If, however, the lyes are merely evaporated and calcined, the organic matter will not be completely destroyed, however high a temperature may be employed, since the alkali fuses and protects the organic matter from the action of the air. It is better to operate as follows: The liquor is concentrated to 40° Bé. (sp. gr. 1·386), and then mixed with enough sawdust to absorb it completely. The mass is then calcined in thin layers, either on iron plates or in a reverberatory furnace, until a sample extracted with warm water gives only a faintly coloured solution.

The greyish-black calcined mass is a mixture of charcoal with caustic and carbonated alkali: it is very porous, and is therefore easily washed out. Instead of extracting it with water, the weak liquors from the decomposition of sodium oxalate with lime may be used. The lye obtained is causticised with lime and concentrated to 42° Bé. (sp. gr. 1·407), and is then used again in the process.

2. Thorn's Process.

Very little has been published on the subject of the most advantageous conditions for treating sawdust with alkalis for the production of oxalic acid; it appears therefore desirable to give the results of the experiments made by Thorn on this subject.

Thorn's earlier experiments were made in round iron pots 2 inches deep, 4 inches in diameter at the bottom and 5 inches diameter at the top; the whole quantity of sawdust taken was thrown into the boiling lye, which was of 30 to 42° Bé. strength, and the heating was continued over a free flame, with continued stirring. By using the more con-

centrated lye of 42° Bé. strength the whole was at once absorbed by the sawdust, and the inconvenient splashing of the liquid was prevented.

In the course of the experiments Thorn observed that variations in the yield resulted from heating the mixture in thicker or thinner layers: a second series of experiments was therefore made in shallow sheet-iron dishes, in which the mixture formed a layer only $\frac{2}{5}$ to $\frac{3}{5}$ inch thick. Pine-wood sawdust, containing 15 per cent. of hygroscopic moisture, was employed for the experiments. To estimate the oxalic acid produced, 1 gram of the melt was treated with warm water, the solution being acidified with acetic acid, boiled to expel carbonic acid, and precipitated with calcium chloride; the washed precipitate was converted into calcium sulphate for weighing, and the amount of crystallised oxalic acid, $C_2H_2O_4 + 2H_2O$, per 100 parts of wood, was calculated.

1. *Formation of Oxalic Acid by Fusing Sawdust with Sodium Hydroxide alone.*

In one series of experiments 1 part of sawdust was added to a quantity of soda lye containing 2 parts of sodium hydroxide; in another series 4 parts of sodium hydroxide were taken. The following were the results obtained:—

50 grams of sawdust fused with 100 grams of NaHO in the iron pot yielded:—

At 200° C., 36·0 parts of oxalic acid per 100 parts of wood.
At 240° C., 33·2 ,, ,, ,, ,, ,, ,,

When the mixture was heated in a thin layer:—

At 200° C., 34·68 parts of oxalic acid per 100 parts of wood.
At 220° C., 31·60 ,, ,, ,, ,, ,, ,,

Using 25 grams of sawdust to 100 grams of NaHO:—
In the iron pot:—

At 240° C., 42·30 parts of oxalic acid per 100 parts of wood.

In thin layers:—

At 240° C., 52·14 parts of oxalic acid per 100 parts of wood.

The colour of the melt passed from brown to a bright turmeric yellow; above 180° the mass assumed a green or brownish-green colour; and at still higher temperatures a vapour with a disagreeable odour was evolved, indicating apparently that more extensive decomposition was taking place. Heating above 200° entailed great care to prevent the temperature from rising too high and causing the redecomposition of the oxalic acid produced. This was especially the case with the smaller proportion of alkali.

2. *Formation of Oxalic Acid by Fusing Sawdust with a Mixture of Sodium Hydroxide and Potassium Hydroxide, in Thick Layers.*

Earlier experiments had shown that, by using a mixture of potassium hydroxide and sodium hydroxide in certain proportions, the yield of oxalic acid equalled, or even exceeded, that with potassium hydroxide alone.

The proportions which give the most favourable result have been very variously stated. According to a report by Fleck, a mixture of $1\frac{1}{2}$ parts of potassium hydroxide to 1 part of sodium hydroxide was employed in an English works: according to another statement 1 equivalent of potassium hydroxide is taken to $1\frac{1}{2}$ equivalents of sodium hydroxide: at Kunheim's factory in Berlin molecular proportions of KOH and NaOH are regarded as the most advantageous, which proportions agree approximately with those first stated above.

Starting with a mixture of 10 parts of potassium hydroxide, 90 parts of sodium hydroxide, and 50 parts of sawdust, Thorn observed that, with the alkalis in this ratio, the mass underwent a peculiar decomposition. Whether the mixture was heated up slowly or rapidly the

colour of the mass passed from brownish-yellow to greenish-yellow, and when 180° was reached the mixture had the consistence of stiff dough. A dense smoke now rose from the melt: and in spite of the removal of the flame, the temperature, increased, at first slowly, then rapidly, in the course of a few minutes, to above 360°. The mass intumesced, and formed craters from which issued large volumes of combustible gas: finally it became completely carbonised. The decomposition could not be arrested by blowing a strong current of cold air upon the mass. As often as Thorn repeated the experiment with these proportions he observed the same phenomena. When a mixture of 20 parts of KOH, 80 of NaOH, and 50 of sawdust was used, the temperature could be raised to considerably above 200° without this uncontrollable decomposition ensuing.

As the proportion of potash is increased, the colour of the finished melt passes from yellow more and more into brown, and higher temperatures are required to produce the same consistence. Above 200° the mixture again becomes fluid, and froths so violently that it comes over the edge of the pot; with further heating it again becomes viscous. It is then difficult to raise its temperature, but if, after heating to 200°, it is cooled to 60 to 80°—stirring all the time to prevent the formation of lumps and to obtain a loose granular mass—it can easily be reheated to 240 to 250°. At this temperature the humus appears to undergo decomposition to some extent, as is evident from the paler colour of the solution, compared with that of a less strongly-heated melt. On the other hand the formation of oxalic acid increases at this high temperature, as is shown by the following experiments, in which 50 grams of sawdust were fused with 100 grams of alkali containing different proportions of KOH and NaOH. Each fusion lasted $\frac{3}{4}$ to 1 hour:—

Proportion of KOH : NaOH.	Temperature in degrees Cent.	Number of Experiments.	Percentage of Oxalic Acid.
20 : 80	190	2	19·78
20 : 80	200	1	21·50
20 : 80	240	2	30·04
30 : 70	190	3	21·38
30 : 70	240	4	38·89
40 : 60	190	1	14·00
40 : 60	200	3	30·35
40 : 60	240 to 245	4	43·70
50 : 50	200	2	25·76
50 : 50	240 to 245	4	39·04
60 : 40	200	3	30·57
60 : 40	240 to 245	4	42·67
80 : 20	200 to 220	4	45·59
80 : 20	240	3	61·32
90 : 10	240	2	64·24
100 : 0	240 to 245	3	65·51

Very different results were obtained when the mixture was heated in thin layers.

3. *Formation of Oxalic Acid by Heating Sawdust with a Mixture of Potassium Hydroxide and Sodium Hydroxide, in Thin Layers.*

As before, 50 grams of sawdust was thrown into boiling lye of 42° Bé., containing 100 grams of alkali hydroxide. The sawdust absorbed the whole of the liquid, and the mixture was then heated on an iron plate in a layer about $\frac{2}{3}$ inch thick. By vigorous stirring, the melting of the mass was, as far as possible, prevented, but above 200° a certain amount of fusion took place, and the mass acquired a pasty, granular consistence. When both alkalis were used this tendency to crumble increased, whilst the colour of the melt remained paler. The mass remained more porous than when heated in a thick layer, and was therefore better exposed to the action of the air. The increased contact with the air is advantageous, inasmuch as it assists

the evaporation of the water, and promotes the oxidation of the woody fibre, which conduces to the formation of oxalic acid as is shown by the following results. The heating lasted 1 to $1\frac{1}{2}$ hours:—

Proportion of KOH : NaOH.	Temperature in degrees Cent.	Number of Experiments.	Percentage of Oxalic Acid.
0 : 100	200 to 220	2	33·14
10 : 90	230	2	58·36
20 : 80	240 to 250	4	74·76
30 : 70	240 to 250	3	76·77
40 : 60	240 to 250	6	80·57
60 : 40	240 to 250	6	80·08
80 : 20	245	4	81·24
100 : 0	240 to 250	6	81·23

This method of heating in thin layers, avoiding fusion as far as possible, gave therefore a considerably larger yield of oxalic acid. The experiments showed further that a mixture of 40 parts of KOH and 60 of NaOH, which approximates to 1 equivalent of the former to 2 equivalents of the latter, gives practically the same yield as KOH alone. With smaller proportions of potash the yield rapidly falls off.

4. *Formation of Oxalic Acid by Heating Sawdust with Alkali Hydroxide, in Thin Layers in a Current of Heated Air.*

If a current of heated air is passed over the mixture during the heating up, the latter retains its pulverulent condition for some time, and first begins to soften at about 220°. The mass, which up to that temperature was of a uniform brown colour, began to show isolated black patches, which rapidly extended throughout the whole. The mixture was heated to 215° in air warmed to 100°; the temperature then rose of itself to 240°, whilst the

mass became of a dark-brown colour. When a mixture of KOH and NaOH was used, the reaction did not take place so violently as with KOH alone, and the mass remained of a paler colour. When air heated to 120° was employed, the temperature rose rapidly from 190° to 250°, and the time required for heating up was materially shortened by the employment of heated air.

The experiments in which 50 grams of sawdust and 100 grams of KOH were taken gave the following results :—

Temperature of the Air.	Temperature to which the Mass was Heated.	Temperature acquired by the Mass after ceasing to apply Heat.	Number of Experiments.	Percentage of Oxalic Acid.
120°	220°	250°	2	78·27
100°	215°	240°	2	82·00
100°	220°	240°	2	82·60
100°	190°	240°	2	79·52
100°	190°	250°	2	80·64

The yield of oxalic acid was therefore no larger than in the experiments without heated air, but a shorter time of heating was required for the formation of the acid.

5. *Formation of Oxalic Acid with the Assistance of Manganese Dioxide.*

In 1858 Possoz took out an English patent, according to which the formation of ulmates, acetates, formates, and carbonates was avoided by heating 100 parts of bran, or other organic substance, with 100 parts of potassium hydroxide and 500 parts of potassium manganate, at 160 to 240° C., but not exceeding 260°.

Instead of potassium manganate, Thorn endeavoured to act on the heated mixture of sawdust and alkali hydroxide with manganese dioxide. The sawdust (50 grams) was heated with the alkali in a thin layer, and at 150°

10 grams of manganese dioxide was scattered over the surface. With 50 grams of wood, 100 grams of KOH and 100 grams of manganese dioxide, the average yield from four closely concordant experiments was 78·74 per cent. of oxalic acid: the addition of the manganese peroxide was therefore without any influence on the yield, and it did not appear that the dioxide underwent any change.

6. *Yield of Oxalic Acid from Different Kinds of Wood.*

To ascertain whether the kind of wood used would influence the yield of oxalic acid, several different kinds were tried. For each experiment 50 grams of wood were heated with 40 grams of KOH and 60 grams of NaOH at 240 to 250° C. in a thin layer, and the following average results were obtained in four fairly concordant experiments :—

	Percentage of Hygroscopic Moisture.	Percentage of Oxalic Acid.	Percentage of Oxalic Acid on Dry Wood.
White deal . . .	15·0	80·50	94·70
Yellow deal . .	15·0	80·50	94·70
Poplar	14·0	80·10	93·14
Beech	8·6	79·00	86·43
Oak	6·5	75·12	84·42

The soft woods therefore give a larger yield than the hard woods.

7. *Yield of Oxalic Acid with Different Proportions of Wood and Alkali.*

If the quantity of wood is increased in proportion to the alkali, subsidiary decompositions of the wood take place, the wood undergoing dry distillation, and ultimately carbonisation. When 75 grams of wood were heated along

with 100 grams of KOH, the mass began to fuse at 210°, and at 215° some black patches appeared in the pale-brown mass. The temperature rose slowly by itself to 250° and the mass turned quite black. With 100 grams of wood to 100 grams of KOH, the mixture became dark coloured even below 200°. In each of the following experiments 100 grams of KOH were employed, and the mass was heated to 250°:—

Quantity of Wood.	Yield of Oxalic Acid per 100 of Wood.	Yield of Oxalic Acid per 100 of KOH.	Mode of Heating.
Grams.			
50	65·50	32·75	Melted in thick layers.
60	54·56	32·73	
75	52·00	39·00	
80	47·12	37·70	
100	36·15	36·15	
50	81·00	40·49	Heated in thin layers.
60	76·30	45·78	
75	68·90	51·76	
80	66·77	53·41	
100	54·14	54·14	

In all the above cases the melting in thick layers gave a smaller yield than the corresponding mixture heated in thin layers. With the former of the two methods of heating, the proportion of 75 of wood to 100 of KOH appears the most favourable when the yield is calculated per unit quantity of the potash used: but with heating in a thin layer, the yield, calculated on the alkali, rises as the proportion of wood is increased. Considering the relatively low cost of the sawdust compared with that of the potash, it would appear advisable to take such proportions as would give the largest yield for a given quantity of alkali; but there are practical difficulties in conducting the fusion and in the subsequent purification of the oxalic acid, which

prohibit the use of much more than 50 parts of wood to 100 of alkali hydroxide.

The extraction of the oxalic acid from the melt can be performed in two different ways: the aqueous extract of the melt may be boiled straight away with milk of lime, to precipitate the oxalic acid as calcium oxalate, or, if both alkalis have been employed, the sodium oxalate may first be separated out by crystallisation.

Working by the former of the two methods a large quantity of calcium carbonate is precipitated with the calcium oxalate; this consumes an equivalent quantity of sulphuric acid, and therefore occasions a larger expenditure of both lime and acid than corresponds to the oxalic acid obtained. The size of the apparatus and the amount of fuel also have to be increased, because the amount of washing required, and therefore the quantity of liquid to be dealt with, increases as the quantity of precipitate augments.

Besides this, it is difficult to obtain pure oxalic acid from the precipitate prepared in this manner, because the humus substances which the solution contains are precipitated by the lime and adhere very obstinately to the precipitate, and on the subsequent decomposition with sulphuric acid yield a dark-coloured solution of oxalic acid. The whole of the alkali is recovered in the caustic state, but the liquor cannot be directly employed for another melting operation, on account of the large quantity of organic matter which it contains, but must first be evaporated, calcined, and again causticised, thus entailing a second consumption of lime. It is therefore far more advantageous to first crystallise out the sodium oxalate, the additional operation being fully compensated by the avoidance of the above disadvantages. The process of manufacturing oxalic acid from the melt may therefore be divided into the following five operations:—

1. Preparation of the solution.

2. Crystallisation of the sodium oxalate.
3. Conversion of the sodium oxalate into calcium oxalate.
4. Decomposition of the calcium oxalate by sulphuric acid.
5. Crystallisation of the oxalic acid.

1. *Preparation of the Solution.*

The mass obtained by melting sawdust with the alkalis is boiled with water until nearly the whole of it is dissolved: the solution is then evaporated to 38° Bé.

2. *Crystallisation of the Sodium Oxalate.*

The solution becomes very slimy during concentration, in consequence of the presence of the humus; and this introduces difficulties into the operation of separating the fine-grained crystals of the sodium salt from the mother liquor. If 4 parts of alkali are used with only 1 part of wood, practically the whole of the oxalic acid crystallises out (as sodium oxalate) from a solution concentrated to 38° Bé., and the mother liquor can be readily run off from the crystals, which are therefore left at once in a comparatively pure condition. If, however, only 2 parts of alkali are used with 1 part of wood, the mother liquor is very syrupy, so that it cannot be removed from the crystals by decantation or by ordinary filtration, and special arrangements for the separation become necessary. In the small-scale experiments a Bunsen filter-pump was used. By this the mother liquor was sucked out from the crystalline magma as completely as possible, and the crystals were then washed with small quantities of cold water until oxalic acid began to appear in the filtrate. In this way a fairly pure, pale-brown sodium oxalate was

obtained. On the large scale, filter presses or centrifugal machines are used for separating the mother liquor from the crystals.

The sodium oxalate separates out in the form of a sandy powder which exhibits no definite crystalline forms. It forms rounded granules about the size of rape-seed; the larger granules are frequently hollow, and scales resembling the husks of hemp-seed are often observed at the edges of the crystalliser.

Another method consists in treating the melt with water at 16° C., by which the caustic and carbonated alkalis are dissolved, whilst the sodium oxalate remains undissolved. According to Thorn's experiments, however, although most of the sodium oxalate remains behind, a not inconsiderable amount of oxalic acid passes into solution, probably as potassium oxalate, which then must be precipitated with lime. If, on the contrary, the melt is dissolved completely by boiling, and the sodium oxalate allowed to crystallise, it is possible to obtain a mother liquor practically free from oxalic acid, because the potassium oxalate present in the melt is completely converted into sodium oxalate during the boiling.

3. *Conversion of the Sodium Oxalate into Calcium Oxalate.*

The sodium salt is dissolved in boiling water, a small excess of milk of lime is gradually added, and the mixture is boiled for about 2 hours. It is advisable to dilute the mixture well with water, since otherwise the decomposition is slow and more lime is necessary. If a filtered sample, acidified with acetic acid, still gives a precipitate with calcium chloride, more lime must be added. When the decomposition is complete, the caustic lye is drawn off, the precipitate being boiled several times with water and collected on a filter.

4. *Decomposition of the Calcium Oxalate by Sulphuric Acid.*

For this operation a large excess of sulphuric acid is always necessary, 3 equivalents being required for 1 equivalent of the oxalate. It is important in this operation to add an ample quantity of water to ensure the complete action of the acid. The calcium oxalate is therefore stirred up with water to a thin paste, and the requisite quantity of sulphuric acid (15° to 20° Bé.) is added gradually, with stirring. The paste becomes at first somewhat stiff from the calcium sulphate (gypsum) formed, but after standing for a time becomes thinner and can then be easily stirred, more water being added and the mixture gently heated for 1 to 2 hours with frequent stirring. Too high a temperature must be avoided, as the solution would then acquire a dark colour. When the decomposition is complete the liquid is filtered off and the precipitated gypsum washed: it must be well stirred up with the water as it settles very rapidly.

The gypsum can either be used as manure, or be calcined and used as a plastering material.

5. *Crystallisation of the Oxalic Acid.*

The solution obtained contains, besides the oxalic and sulphuric acids, a small quantity of calcium sulphate. It is concentrated to 15° Bé. (specific gravity 1·116), and on standing for 3 to 4 hours the calcium sulphate separates out in small asbestiform crystals. After removing these, the liquor is further concentrated to 30° Bé. (sp. gr. 1·261); the oxalic acid separates on cooling in long crystals, which are purified by several recrystallisations. The sulphuric acid is used in the next operation; if too much contaminated by organic matter it must be purified by concentration.

3. Bohlig's Process.

Potash lye, of 36° Bé., is heated to boiling in a stout iron pan, and common deal sawdust is added until a thick paste is obtained. The heating is continued with constant stirring, and, when the water has evaporated, the mixture again becomes fluid, homogeneous, and of a turmeric yellow colour. The temperature is maintained at the same height for 2 to 2½ hours, the fire being then drawn and the mass allowed to cool somewhat. Whilst it is still warm, enough water is added to give a solution of 40° Bé. strength: this is allowed to get cold after it has been well mixed by stirring. A very considerable yield of potassium oxalate, which is completely insoluble in potash lye of 40° Bé., is obtained. This method of preparing potassium oxalate is not new, although considerably improved: the subsequent treatment is, however, entirely new.

The well-washed and recrystallised potassium oxalate is dissolved in a large quantity of hot water, and the cooled solution is precipitated with magnesium chloride or sulphate (waste liquor from the manufacture of carbonic acid for soda water). The well-washed magnesium oxalate is heated in a wooden tub by a steam pipe, and concentrated hydrochloric acid is added until it is entirely dissolved. The clarified solution is run hot into stoneware pans, and on cooling yields oxalic acid in clean crystals, which after washing and a single recrystallisation are chemically pure. This rapid and economical process yields oxalic acid without any useless residues, so that it presents an evident advantage compared with previous methods.

4. Process of Roberts, Dale & Co.

Messrs. Roberts, Dale & Co., at their soda works at Warrington, manufacture oxalic acid by gradually adding

fine sawdust to a lye containing 1½ parts of caustic potash and 1 part of caustic soda, in iron pans. The mixture is then evaporated with constant stirring, so as to obtain a moist powdery residue. The caustic soda is thus converted into sparingly soluble sodium oxalate, and the caustic potash into potassium carbonate with small quantities of potassium oxalate. The mass has a brown colour due to the simultaneous formation of humus compounds. The material is thrown into iron filter boxes with wire-gauze false bottoms: water is run upon it and, by the action of a pump connected with the space below the gauze, is drawn through the saline mass, dissolving the potassium salts in its passage. The washed residue, which consists of sodium oxalate, is decomposed by heating with milk of lime, in an iron pan with a horizontal stirrer, calcium oxalate and caustic soda being formed. The soda lye is evaporated and used over again: the calcium oxalate, after it has been washed in the same manner as the sodium oxalate, is decomposed by sulphuric acid in wooden vats lined with lead. The solution of the potash salts separated from the sodium oxalate is likewise boiled with lime, to remove the oxalic acid and causticise the potassium carbonate, and the caustic potash lye obtained is used again as before. The solution of oxalic acid obtained from the decomposition of the calcium oxalate is evaporated to the crystallising point in lead pans, and the crystals obtained from the first and second evaporations are repeatedly recrystallised to eliminate the adhering sulphuric acid. The last mother liquor, diluted with water and mixed with a further quantity of sulphuric acid, is used for the decomposition of fresh quantities of calcium oxalate.

J. Dale has introduced an improvement on this process. It consists in treating the sawdust with a hot solution of soda or potash before fusing it with the caustic alkalis.

This preliminary treatment removes most of the impurities from the wood-cellulose.

5. Preparation of Oxalic Acid from Lignose.

(Chemically Prepared Wood.)

The lignose obtained by treating wood with hydrochloric acid may also be used as the raw material for the manufacture of oxalic acid, the process being the same as that with sawdust. The action of sodium hydroxide on lignose produces a darker mass than when wood is used, the melts are more fluid and more resemble those in which a mixture of potash and soda has been used.

According to Bachet and Machard the treatment with hydrochloric acid dissolves the light spongy cellulose which forms the envelope of the incrusting substance, so that the proportion of lignin in the residue is increased, and the product, freed from the spongy cellulose, is more readily soluble in alkalis. Experiments, in each of which 100 grams of sodium hydroxide were employed, gave the following results :—

Lignose from 50 grams of Wood.	Temperature. Degrees Cent.	Number of Experiments.	Oxalic Acid per 100 parts of Lignose.	Oxalic Acid per 100 parts of Wood.	
32·7	190	2	23·67	15·39	Melted in thick layers.
25·8	190	3	20·79	10·37	
31·1	190	2	22·16	14·09	
31·4	190	1	26·40	16·58	
31·1	240	2	47·66	29·04	
31·4	205	3	31·03	22·58	Heated in thin layers.
31·4	240	2	49·36	31·00	

According to these experiments the yield of oxalic acid is about 33 to 38 per cent. smaller than when the original wood is melted with sodium hydroxide. This would seem

to indicate that the spongy cellulose contributes more to the formation of oxalic acid than the residue left after treatment with hydrochloric acid, containing a larger proportion of lignin, and more readily soluble in alkalis.

6. Manufacture of Oxalic Acid by Zaiher's Process.

In this process the formation of humus substances, which are products of decomposition and oxidation, is avoided by conducting the fusion in a vacuum. The use of a vacuum permits the preliminary fusion to be performed at as low a temperature as 180°. It is advantageous to deprive the sawdust of water and air by heating it in the vacuum vessel before admitting the caustic lye, as this is then readily absorbed by the dry sawdust, and the solution of the cellulose in the alkali takes place more readily. It is also possible to boil the sawdust in the apparatus with water or weak alkaline lye (4° to 6° Bé.), run out this liquor, exhaust the vessel, and then draw in the strong lye and commence the fusion. The vessel used is a steam-jacketed boiler fitted with a stirrer, and with wide valves connected with a condenser or with an air pump, and adapted to be either heated by steam or cooled by water. After heating the boiler to 100°-150°, the calculated quantity of sawdust, or other material containing cellulose, is thrown in, the stirrer is set in motion, and the air is pumped out, by which means the sawdust is freed from air and water. The concentrated alkaline lye, previously heated to a temperature not exceeding 130°, is then drawn in, the stirrer is kept in slow rotation, and whilst maintaining as perfect a vacuum as possible, the temperature is gradually raised to 180°. The preliminary fusion, or preparation of the melt, requires several hours, but when known raw materials are used it requires little attention. The mixture thus obtained is then reheated in

the usual way with access of air, in shallow pans provided with suitable stirrers, and yields a dry, pulverulent, nearly colourless product.

260 parts of white deal or poplar sawdust, containing 20 per cent. of moisture, are placed in the boiler, and dried at 100° to 150° in an almost perfect vacuum, with the stirrer in motion, which takes about 30 minutes: 940 parts of hot (122°) potash lye (46° Bé.) containing 6 to 7 per cent. of potassium carbonate, previously concentrated in a separate vessel, are then admitted, and the preliminary fusion is performed whilst stirring slowly. This is complete in 3 hours. The mixture is then cooled to about 160° and, by reversing the motion of the stirrer, the pale-yellow fluid product is run out into a shallow pan, also provided with stirring apparatus. It is here slowly raised to 320°, stirring all the time, the operation requiring about 4 hours. The product is a light-grey powder, which readily dissolves to a nearly colourless solution in which no undissolved cellulose is present. By direct precipitation with lime it yields a nearly white calcium oxalate. The melt contains 32 per cent. of oxalic acid.

The best proportions are found to be 2½ parts of caustic potash to 1 part of dry sawdust.

CHAPTER IV.

MANUFACTURE OF ALCOHOL FROM WOOD WASTE.

Patent Dyes.

By the prolonged boiling of wood, especially if first reduced to fibres, with dilute mineral acids, part of the cellulose can be converted into sugar. If the saccharine liquid is suitably neutralised and then fermented, the sugar is converted into alcohol, which can then be distilled off.

This process has the appearance of being a very simple and obvious method of manufacturing alcohol; nevertheless in practice a number of difficulties are encountered, so that hitherto very little use has been made of this property of wood.

Braconnot based his process for preparing alcohol from wood on the following facts: When dry cellulose, or wood in a finely divided condition, is mixed with concentrated sulphuric acid, heat being avoided, the wood is converted into a pulp. After several hours this is diluted with water and heated to boiling. After neutralising the acid with lime, the liquid can be fermented, and the fermented solution yields ordinary alcohol on distillation.

In Payen's experiments 500 grams of pine-wood, in pieces 1 centimetre thick, were boiled for ten hours with 2 litres of 10 per cent. hydrochloric acid, whereupon the liquid was found to contain 105 grams of dextrose, or 21 per cent. on the dry wood. It was then neutralised and fermented.

In the process given by Zetterlund, the sawdust was heated in a boiler with hydrochloric acid under a pressure of $1\frac{1}{2}$ lbs. per square inch, the liquid being neutralised and fermented in the usual way. The materials used were—

990 lbs. of very damp fir sawdust.
77 ,, of hydrochloric acid of specific gravity 1·18.
3410 ,, of water.

After boiling for 8 hours the mass contained 3·33 per cent. of sugar, and after 11 hours 4·38 per cent.: no further increase could be effected. The whole mass now contained 195 lbs. of grape-sugar, equal to 19·67 per cent. of the weight of sawdust employed. The acid in the mixture was then nearly neutralised with lime, leaving only an acidity equal to $\frac{1}{2}$ degree on Lüdersdorff's acid scale. At a temperature of 30° the yeast from 22 lbs. of malt was added. The fermentation was complete in 26 hours, and the wort yielded on distillation $5\frac{7}{8}$ gallons of 50 per cent. alcohol, of agreeable flavour, and perfectly free from any odour, or taste, of turpentine. It may be assumed that the manufacture of brandy from sawdust on the large scale will become a success when experiments have settled the quantity of water to be added to the acid, and the length of time that the mixture should be boiled, as these two factors have the greatest influence on the formation of the sugar. If it were possible to convert the whole of the cellulose of the sawdust into grape-sugar, 100 parts of air-dried sawdust would yield at least 24 parts of 50 per cent. alcohol. Sawdust from foliage trees would probably give the best results.

Bachet and Machard employ wood cut into discs, which they boil with dilute hydrochloric acid, and ferment the sugar solution so obtained, after neutralising it with calcium carbonate. The calcium chloride formed is inimical to the complete fermentation of the sugar This

difficulty may be met by substituting sulphuric acid for hydrochloric. The sawdust is boiled for 10 hours under high pressure in a copper boiler with a liquid containing 1 to $1\frac{1}{2}$ per cent. of concentrated sulphuric acid, the dark amber-coloured liquid being neutralised with lime and submitted to fermentation with yeast.

The calcium sulphate produced by the neutralisation with lime opposes no obstacle to the complete fermentation of the sugar, but it would seem that substances which are antagonistic are formed by the action of the sulphuric acid on the wood.

The chief difficulties in the way of employing this process on the large scale are that—unless we assume a supply of sawdust to be available—very complicated machinery is required for comminuting the wood to the extent necessary for obtaining a sufficiently large yield of spirit (1 gallon from 1 cwt. of wood), and that in consequence of the bulkiness of the material very large vessels are necessary. It is also difficult to make these vessels so that they will withstand the high pressure and corrosive action of the acid fluid.

Quite recently E. Simonsen has manufactured alcohol on the large scale at the Bache-Wiig works. A steam boiler, with a heating surface of 150·7 square feet, heated by a coal fire, and an autoclave with a capacity of 1650 gallons, lined with lead, were employed. The autoclave was a cylinder, which could be rotated, and was furnished with two manholes, steam pipe, testing and drawing-off taps, and a thermometer. The pressing was effected with an ordinary hydraulic press. For the neutralisation, and subsequent fermentation, wooden tubs, of 660 and 880 gallons capacity respectively, were employed. Two other neutralising tubs, and six auxiliary tubs of 143 and 154 gallons capacity, were required.

The routine of the work was as follows :—

1. The autoclave was charged with 220 lbs. of sawdust and 660 to 1100 lbs. of sulphuric acid (0·5 per cent. strength).

2. Steam was admitted until the temperature reached 100° C.; part of the air was blown off and the taps were all closed.

3. The mixture was heated to 174° C. (135 lbs. pressure per square inch), and boiled for half an hour; the steam was blown off, the autoclave emptied, and the undissolved sawdust pressed.

4. The saccharine solution was neutralised with lime, leaving it, however, feebly acid, and then, at 25° C., was separated from the sediment of gypsum.

5. The necessary yeast, with a small quantity of nutrient material, was added, and the whole was allowed to ferment.

6. At 25° C. the fermentation was generally complete in 3 to 5 days, though occasionally it required longer. Its progress was watched by methodical estimations of the decrease in the percentage of sugar present.

7. Finally, the alcohol was distilled off: a single distillation, giving a 15 per cent. spirit; a second distillation gave alcohol of 75 per cent. strength.

The results obtained may be summarised as follows :—

1. It does not seem to matter whether the sawdust is fine or coarse; regard must be paid to the amount of moisture which it contains, and the amount of water and sulphuric acid must be regulated accordingly.

2. Pine and fir-wood yield approximately the same amount of alcohol, but birch sawdust gives a larger yield of sugar.

3. Wood-shavings are quite as good for the purpose as sawdust, but they must be cut up small, across the grain.

4. The amount of liquid must be in the proportion of 4 parts to 1 part of sawdust.

5. The acid must amount to exactly 1·5 per cent. of the total liquid.

6. The pressed residue may be used as fuel.

7. The quantity of sugar solution obtained varies with the amount of condensed steam and the temperature of the liquid run into the autoclave.

8. The proportion of sugar in the liquid generally approximates to 5 per cent.

9. The total sugar produced amounts to about 22 parts per 100 of dry sawdust: in a small-scale experiment birch sawdust gave a yield of 30·8 per cent.

10. The fermented liquor contains 1·1 to 1·7 per cent. of alcohol: in the most successful operations $\frac{3}{4}$ gallon of absolute alcohol were obtained from 1 cwt. of sawdust containing 20 per cent. of moisture.

11. The quality of the alcohol is most satisfactory.

Patent Dye-Stuffs (Organic Sulphides, Sulpho-dyes or Mercapto-dyes).

By a process which has not become very generally known, Croissant and Bretonnière prepare from sawdust, decayed wood, horn, bran, starch, gluten, etc., dye-stuffs which they call organic sulphides because they contain sulphur replacing hydrogen. For example, to convert bran into a dye, it is placed in an iron pan which has a flanged edge; certain proportions of caustic soda and flowers of sulphur are added, the whole is worked into a uniform mixture, the pan being closed with a cover, and heated to 250° to 300° C. The sodium sulphide which is formed acts on the organic matter, removing hydrogen, which escapes as hydrogen sulphide, and adding sulphur. When the operation is complete, the pan contains a black, friable, hygroscopic mass, which dissolves completely in water. The solution, which is of a fine sap-green colour, smells of

garlic or mercaptan and has a remarkable affinity for organic fibre, which it dyes without the use of a mordant. One and the same organic substance dyes several shades according to the proportions and the temperature employed. Certain substances, such as dye-wood extracts, aloes, etc., yield dyes even at the temperature of boiling water; others, such as wood-fibre, bran, etc., require a higher temperature. We give here two examples :—

1.

Aloes	6 lbs.
Caustic soda solution of 40° Bé.	2 gallons.
Water	2 gallons.
Flowers of sulphur	6 lbs.

By operating at boiling temperature a greyish-lilac is obtained; at a higher temperature a dark brown.

2.

Humus (or rotten sawdust)	45 lbs.
Normal sulphide	9 gallons.

The normal sulphide is made from 17 gallons of 40° Bé. soda lye of $14\frac{1}{2}$ gallons of water and 44 lbs. of sulphur. By the combination of sulphur with various organic substances an almost unlimited series of entirely new dye-stuffs has been obtained. In some cases the sulphur appears to enter into direct combination with the organic substance, without displacing any of its constituents, in which case the reaction takes place at a moderately low temperature, such as 100° to 120° C. This is the case with aloes. In by far the greater number of cases, however, the sulphur combines with the hydrogen of the organic substance, hydrogen sulphide being then evolved and the hydrogen replaced by an atomic equivalent of sulphur. For this reaction, temperatures of 250°, 300° and even higher are necessary. In both cases, however, the substance acquires dyeing properties which it did not previously possess. One

and the same material will yield various shades according to the temperature, the duration of the heating, and the proportion of sulphur compound employed. In general the dye obtained approaches black, or at least brown, is the more soluble in water, and gives the faster dyes the higher the temperature and the greater the length of the heating. The dye obtained from decayed oak is extremely soluble in water; its odour resembles that of garlic or petroleum, and it has great affinity for fabrics. The dye from wheat-bran may be regarded as typical of a series. It differs somewhat in the mode of its preparation from that made from humus, for which previously prepared sulphide is used, the bran being mixed with flowers of sulphur and caustic soda. When this mixture is heated, sodium sulphide is formed, so that the same conditions are produced as in the former case; but as this method allows the proportions of sulphur and soda to be varied, and the resulting shade to be thereby modified, it is preferable to the other.

The dye obtained from wheat-bran is easily and completely soluble in water, has a garlic odour, and has great affinity for fibres, as well as an extraordinary dyeing power. The dyed fabrics are greenish when taken out of the dye-bath, but after immersing in a solution of bichromate of potash acquire a catechu-brown shade, which inclines to grey after treatment with boiling soda. This change is characteristic of the products from bran, etc., and generally of all nitrogenous substances. The tendency to be changed to grey by soda solution is also influenced by the amount of sulphide employed; the larger the quantity of sulphide, the greener is the solution of the dye, and the more marked the change to grey produced by soda.

The dyes obtained from sawdust give particularly fast shades. The best woods for the purpose are oak, beech, cherry, chestnut, etc., whilst the soft resinous woods are

unsuitable. The sawdust must be dry, and finely sifted. It may be converted into humus by piling it in heaps which are watered from time to time, and then gives results almost identical with those of old decayed wood.

Sawdust, which has been moistened with urine for several months with the object of rendering it nitrogenous, yields dyes which behave similarly to those from bran and other nitrogenous substances. The dye from sawdust is almost inodorous, and dissolves in water with a brownish-black colour. The dye is taken up readily by the fibre which it dyes a dark greenish-grey, not altered by bichromate or by soda. The shade is fast to light, acids, air, alkalis, and soap.

These dye-stuffs are very hygroscopic; they must be protected from damp by keeping them in well-closed tins. If this is not done they gradually decompose, absorbing oxygen and becoming insoluble and therefore unfit for use. The same is the case if the dye-bath is prepared too long before it is wanted for use. In a lukewarm bath the dyes have a great affinity for fibres, and give fast shades without the use of any mordant. The older the dye bath the smaller is the affinity of the dye for fabrics; after 4 to 5 months it is destroyed completely. The baths should therefore only be made up in sufficient quantity for immediate use. The quality of the water used for the baths is far from immaterial, calcareous waters being quite unfit for use, since they immediately produce an almost insoluble, flocculent precipitate. The advantages of these patent dyes may be stated as follows: (1) Their manufacture is extremely simple, requiring neither expensive appliances nor complicated apparatus, and but little labour; moreover, the result of the manufacturing operations is perfectly certain. (2) The tinctorial power of these products is considerably greater than that of most other dyes. (3) The dyes are very fast, and resist both acids and alkalis

better than any hitherto employed. (4) They are cheaper than the commonest dyes, especially when their remarkable strength is taken into account. For example, a pound of dye from sawdust costs little more than half as much as logwood extract, but will dye four times as much fabric. The new process is therefore capable of converting into dyes, by a simple method and at a low cost, materials which are everywhere accessible and possess little value; it is moreover capable of producing directly from these materials an unlimited series of completely new dye-stuffs of very divergent shades.

CHAPTER V.

ARTIFICIAL WOOD AND PLASTIC MATERIALS FROM SAWDUST.

Production of Artificial Wood Compositions for Moulded Decorations.

The use of sawdust for the production of plastic compositions, which may be shaped either by pouring or by pressing into moulds, has been known for a considerable time, and the methods for the preparation of these compositions have been so much improved that articles which leave nothing to be desired are now produced by this means. Attempts have been made to manufacture planks, boards, beams, etc., from sawdust, but these endeavours have never met with success, because the lacerated wood-fibres, even when reunited by the most suitable binding materials, no longer possess the elasticity and strength of the natural wood. It is not to be expected that sawdust can ever be made to produce a material equal in all respects to the original wood, and we shall therefore confine our attention to those products which possess a practical value.

The idea of replacing wood by artificial products seems to have originated in China and Japan. Thence the invention reached Europe during the eighteenth century, and was especially applied in England, where, in 1772, Clay took out a patent for the preparation of such materials. Numerous processes for the production of arti-

ficial wood have been published, some of which differ widely from one another. The oldest methods are those in which finely disintegrated vegetable fibres, paper pulp, lime and rice starch are mixed. Later Jennens introduced improvements, and is said to have had a factory at Birmingham where artificial wood articles were manufactured in great variety. The basis of these was chiefly a kind of paper pulp, which, by the addition of glue solution, chalk, clay, and linseed oil, was made into a dough which could be kneaded and shaped, and which acquired great hardness and durability when dried. The product was employed for the ornamentation of ceilings, mirrors, picture frames, etc. A similar material, which could be poured in the liquid state into moulds, was composed of sawdust or other finely subdivided vegetable fibre, refuse hair, and hemp, with glue solution, white of egg, caoutchouc, pitch and turpentine. The "*Simili bois,*" made in Paris, and used with good effect for imitation wood-carvings, is a preparation of the same character. According to a proposal of Brindly, who obtained a patent for its use in manufacturing lacquered wares, tea-caddies, etc., a mixture was made of paper pulp, paper waste, hard soap, and alum.

The general method of preparing these compositions is to mix sawdust with a binding material, and then, according to consistence, either pour or press the mixture into moulds. The articles so prepared may be used for all kinds of decorative work, instead of the more costly wood-carving, especially for frames, small boxes, and various fancy articles. Artificial wood is also employed in making brushes; the bristles are inserted into a slab of the soft composition, which is then covered with a plate, perforated to let the bunches of bristle pass through. The application of pressure binds both into a single mass, and the brushes so made are both cheaper and more

durable than those made by the methods most commonly in use.

The first artificial wood of this kind consisted of a mixture of sawdust, glue, and certain tanning solutions, or of sawdust, turpentine, resin, etc. Latry, in Paris, prepares artificial wood from sawdust and blood albumin by the application of heat and pressure. Very fine sawdust, especially that of poplar-wood, is soaked in diluted blood, and dried at 50° to 60° C. The mixture is submitted to high pressure in steel moulds, which at the same time are heated to 170° to 200° by gas flames. At this temperature the blood undergoes a sort of fusion, and the whole becomes a blackish liquid resembling asphalt. The product is a hard material of woody texture, which can be sawn, glued, polished, lacquered, and gilded, exactly like wood. Articles made of this material were sold as "*Sciffarin ware.*" According to another formula, wood-fibre prepared as for paper-making, was saturated with glue solution, pressed, and dried. This furnished a hard material, which was then protected from the action of moisture by several coats of thick linseed-oil varnish applied hot.

Another composition, bearing a resemblance to these artificial woods, is the so-called *wood marble*, which is made from the sawdust of fine, hard woods, ivory waste and other waste materials, to which pigments are often added. These, by the addition of water-glass, glue, etc., are made up into a hard mass, from which veneers are then cut, which, naturally, are not liable to warp or crack. The material takes an excellent polish, which gives it the appearance of the finest marble.

A composition consisting of $\frac{1}{3}$ of sawdust, $\frac{1}{3}$ of calcium phosphate, and $\frac{1}{3}$ of a gelatinous or resinous material, goes by the name of "*Simili bois*," and is used for the reproduction of sculpture.

Quite recently articles of this character have been made

from sawdust compositions, for the decoration of all kinds of wood work, such as door lintels, brackets, capitals of pillars, cornices of cabinets, panels of chests, decorative mouldings, etc.; and it is well known in the furniture trade that ornamental articles of every kind, and imitation wood-carvings such as are used for furniture, fancy work, toys, as well as for house decoration, are most extensively prepared by moulding. But whilst these manufactures are largely employed in France, England, and America, they appear as yet to have obtained little footing in Germany and Austria. It is difficult to understand why, in spite of the great progress in cabinet work, very little wood-carving is employed in furniture.

These products have been so perfected that for cheap furniture, wall and ceiling decoration, etc., they are capable of completely replacing wood-carving, and such decorations in semi-relief have specially gained acceptance as substitutes for wood-carvings. Articles of artificial wood must fulfil the following requirements:—

1. They must resemble wood as closely in appearance as possible, and have approximately the same specific gravity.

2. They ought not to warp with heat or damp, and must be sufficiently tough, as well as hard, to prevent the edges from breaking off too readily.

3. They must permit of being bored, filed, sawn, cut, and carved, without being brittle: they cannot of course be split, since their structure is perfectly uniform.

4. They must admit of being glued, without special difficulty, to the objects to be decorated, and must adhere well.

In Germany, B. Harrass of Böhlen (Thuringia) has for several years been engaged in the preparation of artificial wood; and the material which he produces fully deserves that name, since his manufactures exhibit the

choicest forms in the various styles, and a great diversity in the individual articles, which are supplied by him as complete ornamental fittings both for furniture and house decoration. The panels and friezes of the Italian Renaissance are altogether unlike the unsightly forms which are still exhibited by the wood-carvings of the German Renaissance. The ornamental objects supplied by Harrass have an artistic character of their own, whilst they are free from the objection to wood-carving on account of its costliness.

Not furniture alone, but the walls and ceilings of our dwellings may by the use of artificial wood, at a cost which scarcely exceeds that of stucco, be decorated with panelling of high architectural quality. As in the dwelling-houses of the present day only the skirting boards and base mouldings form the only relics of the heavy panelling of our predecessors, the patented invention of Harrass supplies the demand which is arising on all sides for the restoration to favour of wood architecture for chamber decoration, inasmuch as the use of artificial wood furnishes every builder with the means of producing, at a low cost, wainscoting equal to the few examples which have come down to us from the best days of the Florentine School.

The manufacture is, however, in no sense an imitation, nor, as the name would seem to imply, a substitute for wood, but in its outward layer consists of natural woods (walnut, oak, mahogany, or rosewood), which Harrass makes plastic by giving them a basis of wood-fibre bound together by albumin into a homogeneous, insoluble mass. The artistic objects produced in this way are far more durable than those made by carving natural wood, are far cheaper, and at the same time better finished than most carvings. To their employment for artistic furniture and house decoration may be added their use for a great variety of other objects, such as photograph frames, mirror

frames, etc., all of which are turned out in an equally finished style.

In the above account I have endeavoured to give a general idea of the amplitude of the field which is open for utilising sawdust in the production of artificial wood. Many have been the attempts made to replace wood-carvings by other and cheaper forms of ornament, such as papier-mâché, and even cast-zinc, but these, partly on account of the difficulty of affixing them, partly in consequence of their want of artistic finish, but mainly because they did not resemble wood in appearance, have never met with success. An obvious expedient therefore appeared to be the use of wood itself for such objects; and already a large number of processes are known, which in recent years have effected marked advances in this direction by means of the employment of wood-cellulose.

The Preparation of Artificial Wood for Moulded Decoration.

As already mentioned all artificial wood-compositions consist of sawdust, or spent dye-woods, and a binding material, which may be of various kinds. The binding material is either soluble in water and remains soluble, or is rendered insoluble by special treatment, or else is insoluble. According to the nature of the binding material, the mixture is either of the consistence of dough, so that it can be pressed into moulds by hand, or it may be fluid and be poured into the mould; lastly, the binding material may be used in such small proportion that the product is merely a more or less dry powder, which can be forced into moulds by very high pressure, sometimes with the assistance of heat. Compositions which are either poured or gently pressed into moulds generally fill these latter imperfectly: on drying, contraction takes place, and the contours are deficient in sharpness and more or less

rounded. On the other hand, compositions which are pressed into moulds in the form of powder are harder, more durable, and sharp in detail, because the high pressure fills all the minute depressions of the mould and causes them to reproduce their effect in the finished article.

Various Processes.

1. The sawdust of soft woods is boiled with a solution of glue and water-glass, and a further quantity of sawdust is then added and well mixed by kneading so that a plastic mass of the consistence of dough is produced. This is pressed between iron plates, then dried and cut up, yielding slabs of any desired size and thickness which, in the dry state are very hard, and fairly resistant to damp. By adding various pigments, as colcothar, vermilion, umber, etc., coloured tiles suitable for flooring, etc., are produced.

2. A mixture is made of—

7 parts of finely sifted sawdust,
1 part of powdered rosin,

and placed on an iron plate covered with a sheet of paper. The plate has a rim as thick as the finished slab is intended to be. A second sheet of paper is laid over the mixture and then a hot iron plate, and the whole is placed in a press and exposed to high pressure.

3. The strongly dried and sifted sawdust is mixed to a suitable consistence with a solution of glue, which is so hot that it can be scarcely borne by the hand. The glue solution is made by soaking 5 parts of good pale glue and 1 part of isinglass in water, heating up slowly and filtering carefully. The quantity of water (variable according to the quality of the glue) should be just large enough to prevent the liquid from gelatinising on getting cold. In some formulæ gum-tragacanth and whiting are added to the glue solution, the former for the purpose of producing

a consistence more resembling that of dough, the latter to give greater hardness. The moulds may be either of metal, plaster of Paris, or sulphur, if oiled; even wooden moulds may be employed if they are first varnished with an alcoholic solution of shellac. A thin layer of the mixture is first pressed into the mould by hand, the mould is then filled up with a mixture made with coarser sawdust, the surface covered with a thick plate and pressed. Before removal from the mould, which is easily done when the cast has dried and shrunk a little, the excess of material is removed by a thin broad knife, so as to give the cast a flat base. Such casts can then be lacquered, gilded, and in general treated like carved-wood decorations, but in consequence of the great shrinkage which occurs during the drying they have no sharpness, and do not exhibit the finer detail of the original. These casts require to be protected from damp, but if slowly dried they are fairly free from any tendency to warp.

4. A mixture is made of—

10	parts	of	glue dissolved in hot water.
4	,,	,,	ground litharge.
8	,,	,,	white lead.
10	,,	,,	fine sawdust.
1	,,	,,	plaster of Paris.

The mixture is poured into oiled two-part moulds, and when cold is removed from the moulds and finished by painting, gilding, bronzing, etc.

5. *Bois Durci.*

This peculiar composition, invented by Latri, of Paris, consists chiefly of fresh blood, mixed with sawdust of hard and resinous woods and pressed by a hydraulic press into iron or steel moulds heated by gas. Under the combined action of heat and pressure the

albumin of the blood solidifies to a very hard material, whilst the iron in the blood unites with the tannins of the sawdust to produce a dark colour. If the interior of the mould is greased before filling, the sticky composition does not adhere to it and is easily removed. It is also necessary to press the composition gradually into the mould, since the heat and pressure cause it to shrink considerably. Some salicylic acid is added to the mixture to prevent the blood from putrefying and developing a disagreeable odour. The composition of the mixture may be varied by adding whiting to the blood and sawdust: this obviates the addition of salicylic acid, and confers much greater hardness on the product. An improvement in the process consists in spreading the mixture on heated iron plates, and after drying, grinding it to powder and pressing it into heated metal moulds. Sawdust, especially that of poplar-wood, is ground to very fine powder, mixed with diluted blood, and dried at 50° to 60° C. This produces a very intimate mixture of the albumin of the blood with the wood-powder. The moulds consist of rings containing matrices of highly polished steel, finely and artistically wrought. The dry powder is filled into the moulds, any excess being avoided, so that after pressing no "fins" are visible. The pressing is done by very powerful hydraulic presses; the moulds are heated by gas, and kept at a definite temperature during the whole operation. The moulds run in grooves, which are so arranged as to prevent any lateral shifting, and are held, by stops, in the proper position for the presses. Each of the hot plates is fitted with gas burners which follow its up and down movement. The gas issues from an annular burner, through the middle of which a blast of air is blown by a fan: the regular heat so produced enables of very well-defined castings to be obtained. The consumption of gas is, however, very considerable, but the convenience of the work com-

pensates for the cost. The function of the albumin in this process is not clear. It was for a long time supposed to correspond with that of the varnish on fabrics, but that cannot be the case when the wood-powder mixed with blood albumin has first been dried. A closer investigation has indicated the presence of a certain quantity of resin in the sawdust, and resin produces a solid compound with albumin. If the sawdust of a white, non-resinous wood, such as beech, is taken, a hard mass may be produced, but it will have little strength, and will not resist the action of boiling water. If 33 per cent. of blood (blood albumin) is added the mass will be harder, but will fall to pieces after 10 to 15 minutes in boiling water. With 66 per cent. of blood the objects are stronger, browner, and more durable, but are not equal to those from resinous wood. It appears therefore that the blood is not indeed indispensable, but is nevertheless extremely serviceable in the manufacture. The blood is turned a deep brown colour by the drying, and exhibits glistening specks, which have a good effect in the finished objects. When heated to 170° to 200° C. the blood undergoes an incipient melting, and acquires great adhesive properties. If the mould is opened whilst hot it is found to contain a soft, blackish, semifluid mass, resembling asphalt. It is in this condition, apparently, that it fills all the fine depressions of the mould, which consequently are reproduced accurately after the cast is cold. The product of the whole operation is a hard, wood-like material, which can be worked in every respect like wood itself. Its specific gravity is 1·3, that of the dried mixture of sawdust and albumin being 0·8. This material is worthy of general attention, not only from a technical but from an artistic standpoint.

6. *Gottschalk's "Hartholz" (Hard Wood).*

Gottschalk of Berlin imitates ebony by means of a composition similar to that of Latri, which he prepares with blood albumin and sawdust dyed black. Finely sifted sawdust of hard woods is boiled for 10 hours with a solution of 8 parts of logwood extract and 1 part of alum in 40 parts of water, then drained and immersed for 5 hours in a bath consisting of 1 part of copper vitriol in 15 parts of water. After removal from the bath the sawdust is put through a centrifugal machine and then dried. It is then mixed with blood albumin, and, in the state of coarse powder, is pressed into heated moulds by a stamping press.

7. *Harrass' Imitation Wood from Cellulose.*

The composition employed by Harrass consists mainly of cellulose, sawdust of soft woods, and an albuminous binding material. The chief feature of this composition is the employment, together with sawdust, of wood-fibre which has been decorticated by chemical treatment, by which means greater durability and strength are secured. Harrass, having failed to get completely satisfactory results when using merely ground wood-fibre by itself, turned his attention to cellulose, and with this obtained a most admirable composition. The cellulose is prepared by cutting up pine-wood, freed from bark and twigs, into small pieces, which are then boiled with concentrated caustic soda under a pressure of 150 lbs. per square inch in large iron boilers. By this treatment the wood is resolved into its constituent fibres. The fibrous pulp is thoroughly washed from the adhering alkali by a stream of water, then bleached by chloride of lime, rewashed and dried. This treatment removes both the natural colouring matters of the wood and those

albuminous and gummy constituents which bind the fibres together, and the process of Harrass aims at reuniting the cellulose fibres by the addition of binding materials of similar character.

Cellulose, as supplied by various manufacturers, is in the form of thin, soft slabs, which require to be soaked in water before using the material for the preparation of artificial wood. The excess of water is removed by squeezing the pulpy mass on a fine sieve. A mixture is then made of 4 parts of the cellulose, 4 parts of sawdust, 2 parts of albumin, and 1 part of powdered gallnuts or ground oak-bark ; enough water is added to form a stiff paste, and the whole is stirred until thoroughly mixed. The paste is then passed between rollers, which deliver it in slabs about half an inch thick and of any convenient length ; it is then dried, first in the air and then in stoves, on frames over which netting is stretched. The dried slabs are now in the form of fairly hard cakes of a greyish-yellow colour. They have the property of softening by heat, and therefore, when compressed into strongly heated metal moulds, they receive, and when cold retain, the impress of the dies.

The metal moulds are hollowed to the desired pattern, and the presses employed are coining presses, worked by a lever or wheel, such as are used for stamping and punching metals. Larger or smaller presses, and higher or lower pressure are made use of according to the dimensions of the article to be produced. The presses most recently adopted have been on the principle of the stamping mill, driven by gearing, and can be attended to by a single workman. The moulds receive their heat from the tables of the presses, in each of which there are two or three holes, into which gas is conveyed by flexible tubing, to produce the heat. The temperature must be kept uniform by regulating the gas flames, and must never be so high as a red-heat. The

temperature is adjusted by observing the melting of certain metallic alloys, and the entire manipulation, simple as it appears, requires the greatest experience and precision. The moulds are either of cast-steel or bronze, and consist of two parts, the matrix and the core, which also forms the cover. The former is hollowed out to the exact shape of the pattern, whilst the latter has only the general contour of the pattern in relief, and when placed on the matrix the space between the two surfaces is exactly of the dimensions which the casting is to assume when complete. These moulds are prepared, by casting, from the design carved or modelled by the artist, and are finished by a metal engraver, to give them the sharpness of detail and smoothness in which the rough casting may be deficient. The moulds for producing the capitals of pillars are made in four or more portions, and require the most exact and careful finishing, which considerably adds to the cost of production. The moulds themselves must have a sufficient thickness of metal to resist the high pressure to which they are subjected. No definite rule for the necessary thickness can be laid down, as it depends on the depth of the matrix and the pressure to which it will be exposed. For small objects a thickness of $\frac{1}{10}$ inch is sufficient, whilst for large ones a thickness of $\frac{2}{5}$ inch may be necessary.

To commence an operation, the empty mould is placed with its cover between the heated table and ram of the press, and is left there until it has acquired the temperature of the press plates. After the interior surfaces of the mould and core have been thinly and uniformly greased or oiled, the requisite quantity of the finely powdered composition is introduced, the cover is replaced, and the mass is gradually compressed by working the press. The skill and attention of the workman are here called into play, as he has to judge the moment for ceasing to apply

pressure, and the time for removing the finished article from the mould. If, when removed, the surface shows imperfections, the object is immediately replaced in the mould, a little composition being added at the imperfect places, and is pressed again. Any excess of the composition escapes between the mould and the core, forming a flat border surrounding the base of the casting, and requiring to be removed with a knife or chisel when the casting is cold. The base or back of the object is then ground down on a revolving emery wheel, both to reduce the object to its proper elevation and to form a flat base for securing it by glue or screws. Instead of the emery wheel, a wooden wheel covered with sand-paper or glass-paper may be used. To prevent the freshly pressed objects from warping, it is necessary to lay them, whilst still warm, with their backs resting on a flat plate, and either to load them with weights or to clamp them down and then leave them to get perfectly cold.

In their original state the objects produced in this manner from the cellulose composition are either brownish-grey or yellowish-grey and have a metallic lustre; they can either be coloured in the mass, especially when a black colour is desired, or any desired wood colour, or other shade, can be given to their surfaces by simple processes.

The finished objects require to be kept in dry, well-aired rooms; the damp, musty air of unventilated rooms is as injurious to them as to any other wood-work. They are secured in the same way as wood-carvings; being first warmed and then coated with moderately thick, freshly-melted, hot glue, and applied to the wood-surface to which they are to be attached, which is also previously warmed. When possible they should be held down with screw clamps until the glue has thoroughly hardened. When glued to polished or lacquered surfaces, the polish or lacquer must first be removed at the places where the

moulding is to be attached. It is also very advisable to insert, here and there, small round-headed wood-screws, and in almost any moulding recesses can be found where the screw heads will be out of sight. To obtain as large a surface as possible for glueing, the hollow at the back of the object may be filled up; this is best done by glueing-in a piece of wood which fills the hollow exactly, or the hollow may be filled with a composition consisting of 2 parts of sawdust and 1 part of plaster of Paris, made into a stiff paste with weak glue, and pressed into the hollow after the inner surface has been well brushed over with hot glue. The back is then struck off flat and smooth, and the composition allowed to get dry before it is attached to the surface which is to be decorated. Column and pilaster capitals are best attached by cutting a square tenon, at the top of the wood-column or pilaster, exactly the size of the hollow in the bottom of the moulded capital. The tenon is well coated with glue, and the capital secured firmly by screws. Should any of the objects have become warped, so that the rear surface is no longer truly plane, which is generally due to want of care in storing, the object only needs to be warmed, when it will become flexible, and in that state can be glued in the desired situation and screwed down until the glue has hardened.

By the same means flat pieces can, if desired, be bent to a curved or wavy shape, but the bending must be gradual and careful to avoid fracture. After cooling, the pieces so bent retain their new form. Small irregularities, occurring either in the glueing of the pieces to their supports, or in fitting together the various parts of a moulding, can be rectified, as in the case of ordinary wood, by filing and filling up with some cement. If in fitting the various pieces together any small gaps should be left, these may be filled up with a special wood-cement which is supplied.

Corners which do not fit exactly may be touched up with a file. Any smoothing required is best done with fine sand-paper or glass-paper, but it is advisable first to give the objects a coat of French polish and allow them to dry thoroughly.

8. *Hurtig's Wood-composition for Parquetry, Blocks, Tiles, and Other Decorative Objects.*

Hurtig's process for the production of a wood-composition consists in the manufacture of a waterproof, heat-resisting, compressible powder, and in specially treating natural wood, together with the preparation of the requisite waterproof binding material for uniting the two. The powder, like that of Harrass, when pressed into heated metal moulds, unites to a solid body of any desired shape.

For the preparation of the powder, sawdust from any kind of wood is thoroughly incorporated with a strong aqueous solution of curd soap, and is then thoroughly dried. The powder is next treated with milk of lime and again dried, by which means a material quite unaffected by water is produced. To this powder a quantity of air-slaked lime is added, and the mixture is then thoroughly saturated with a solution of ordinary water-glass (sodium silicate), and once more air-dried. The water-glass serves as the binding material for the powder, and the air-slaked lime is added to produce an insoluble compound with this substance. The dry powder prepared in this way possesses the property of uniting into a solid body when pressed into heated moulds, and is then capable of resisting the action of water, heat, cold, etc.

The following proportions afford serviceable results: 1 cwt. of sawdust from any kind of wood is soaked in a solution of 3 lbs. of common curd soap, with a sufficient quantity of water to wet the sawdust thoroughly with the

solution. After drying it is mixed with milk of lime made from $4\frac{1}{2}$ lbs. of slaked lime. It is again dried and then mixed with $4\frac{1}{2}$ lbs. of air-slaked lime. This mixture is then thrown into a bath prepared with $8\frac{3}{4}$ pints of water-glass of 33° Bé. strength and a sufficient quantity of water. The thoroughly wetted powder is once more dried, and is then ready for pressing. It yields blocks of stony hardness, which are particularly suitable for laying down parquet floors, as they are unaffected by weather and heat, which is not altogether the case with natural wood. It may also be used for the production of all sorts of household utensils, such as plates, cups, basins, etc. For this purpose the powder is filled into the previously heated moulds and then submitted to pressure; it penetrates into all the depressions of the mould, and on cooling hardens and retains its acquired form.

The pressed blocks may be furnished with a facing layer of natural wood (or any other material), for which purpose they are first coated with the following composition: 2 parts of glue are melted with water, and poured into 1 part of hot boiled linseed-oil; 1 part of rosin dissolved in spirit, and mixed with $\frac{1}{2}$ part of turpentine is then added. This mixture is well stirred together in a vessel immersed in boiling water, and is laid on hot. This cement is unaffected by water, and is not liable to the formation of air bubbles. After laying it on the surface of the pressed block it is allowed to cool until it forms a solid crust, and the block is then ready to receive the facing layer. This layer, when the blocks are intended for parquetry, is a mosaic pattern of wooden slabs, and for other purposes may consist of thin plates of copper, brass, or alloy, or of plain veneer or inlaid wood, or of wood with metal fillets, or tarsiatura work of metal inlaid with tortoise-shell, or composite work of any desired description,

When the upper layer is to consist of wood it is necessary that this should be treated to render it waterproof, which is effected in the following manner: A bath is prepared, consisting of 2 parts of concentrated sulphuric acid and 1 part of water, and in this the pieces of wood are immersed. As soon as the liquid has thoroughly penetrated the wood, the latter is well washed by soaking in pure water, rinsed, and dried. It is then immersed in a solution of common curd soap in a convenient quantity of water, and when thoroughly saturated with this solution it is again dried. It is next placed in milk of lime, made up of slaked lime and a quantity of water which varies in accordance with the porosity of the wood; and, when the lime has completely penetrated, it is once more dried. The wood is now perfectly waterproof, and is ready for employment in the production of parquetry, tarsiatura, marquetry, etc., or for forming the outer layer of any of the pressed objects made according to the above process. To ensure firm adhesion, it is applied to the surface of the pressed object which has already been covered with the waterproof cement, and the composite object is then replaced in the same heated mould as was used for the compression of the powder. The heat softens the cement and, by prolonged pressure, the outer layer of wood is so firmly joined to the moulded object that the two cannot be separated after complete cooling.

The articles prepared by the above process are said neither to swell nor shrink, neither do they get soft; they also resist the action of moisture, and even of rain, completely.

9. *Hurtig's Improved Wood-composition.*

Hurtig has recently improved his process, and now operates as follows: In the preparation of the powder

to be formed, by pressure, into objects in relief, it is desirable to add materials to the powder which will give it greater plasticity than is required for objects with plane surfaces. The mode of preparing the powder is varied according to whether high relief or low relief is required.

A. *Preparation of the Powder for Low Relief.*—To the sawdust, which has been treated with soap and milk of lime and then air-dried, a mixture of casein and air-slaked lime is added. The lime and casein should first be allowed to react until they form a pasty mass or liquid. After the sawdust has been thoroughly saturated with this liquid it is air-dried, and is then ready for pressing. Suitable proportions are: 5 to 10 parts, by volume, of sawdust 0·1 to 0·5 part of soap, 3 to 8 of casein which has been combined with 0·5 to 3·0 parts of dry air-slaked lime. These proportions are the limits within which the quantities may be varied; but it is not asserted that these limits are in no case to be exceeded.

B. *Preparation of the Powder for High Relief.*—For the production of objects in high relief, from deep moulds, it is necessary that the powder should not only possess great plasticity, but that whilst warm it should remain flexible in order that it may be removed from the mould without injury, and should harden only when it becomes cold. This is attained in the following manner: Ripe potatoes are dried in their skins, till they have lost 20 to 30 per cent. of their water. They are then crushed, and mixed with fine infusorial earth and a little Burgundy pitch. This mixture is added to the wet sawdust, and after mixing well the whole is air-dried. It is desirable to use unpeeled potatoes in order that the corky tissue of the skins, and the albuminous substances of the layer of cells immediately below the skin, may remain in the mixture. The proportions are as follows: 10 to 30 parts,

by volume, of prepared sawdust, 15 to 40 of crushed potatoes, 1 to 5 of infusorial earth, and 0·5 to 2·5 of Burgundy pitch. These proportions also can be varied if necessary.

The powder thus prepared has not only the high degree of plasticity required, but also retains its original pale colour even in very hot moulds. Any desired colour can be imparted by the addition of mineral pigments which are not altered by heat, so that, in all cases where the outer layer is to consist of metal, the colour of the body may harmonise with that of the applied coating. The pressing and other treatment of this powder are performed exactly as described above.

10. *Kletzinsky's Wood-paste.*

One hundred parts of wood-meal, preferably that of soft varieties of wood, are well boiled in a solution of 100 parts of aluminium sulphate, and then left to become cold: 50 parts of glue are dissolved in 100 parts of boiling water and intimately mixed with the wood-meal pulp, the paste being rolled out into slabs and somewhat strongly pressed. The slabs, which at first are very brittle, acquire by slow air-drying an extraordinary degree of hardness; as soon as they are hard enough they are moistened three to five times with a 5 per cent. solution of potash in water, and are then finally dried. By this means the individual wood-particles become cemented together by a compound of gelatin and alumina, which is insoluble in water, and when dry has the hardness of horn. If it is desired to produce a coloured paste the meal of raw dye-woods may be used, or any suitable colouring matter may be added; or a mottled appearance may be given by adding variously coloured wood-meal and mixing slightly.

11. *Terra-cotta Wood.*

This artificial product is prepared by Gillmann's process in the following manner: According to the degree of porosity which it is desired to obtain, 1 to 2 parts of sawdust from resinous wood are mixed with 1 part of pulped china-clay and, by the addition of a suitable quantity of water a plastic mass of spongy texture is prepared, which is then submitted to the strong pressure of a steel piston in a metallic cylinder. This produces cylindrical blocks 8 to 12 inches in diameter and 47 to 75 inches long. These are first air-dried, then dried in a stove, and finally baked at a white-heat in a kiln, and slowly cooled. The blocks are extraordinarily refractory, and are capable of being sawn, cut, planed and polished. Their density is about half that of ordinary bricks. These blocks have great strength, and are employed for architectural purposes.

12. *Palmer's Wood-composition.*

This material, which is also used as a substitute for wood-carvings, consists of blood, sawdust, bone-dust, and glue. The blood is dried without coagulating its albumin, and is then mixed with a suitable quantity of sawdust, 20 per cent. of bone-dust, and 10 per cent of glue solution, and is strongly pressed into moulds at a temperature of 120° C.

13. *Billefeld's Artificial Wood.*

C. Billefeld has produced a number of these compositions. That for making casts, by pouring in a liquid state into a mould, consists of a mixture of vegetable fibre, paper pulp, caoutchouc, glue, balsam of sulphur (a solution of sulphur in linseed oil), glycerine,

and gluten. Another composition for the same purpose consists of paper pulp, vegetable fibre, tannin-gelatin, gutta-percha, Venice turpentine, balsam of sulphur, and gluten. The tannin-gelatin is prepared by treating glue with the tannin from oak-bark. A third composition, from which billiard-tables and similar articles can be made, is prepared from a paste of 80 parts of water, 32 parts of flour, 9 parts of alum, and one part of iron vitriol; then 15 parts of rosin and 10 parts of linseed oil are boiled with 1 part of flake litharge, and finally 35 to 60 parts of tow, or, better, wood-pulp, are added. The solid constituents are ground as fine as possible, and the whole paste is well kneaded together and rolled out. It is then treated with hot linseed oil to render it waterproof. Objects, such as bas-reliefs, capitals, cornices, etc., were shown by Bellefeld in the London Exhibition of 1862. These compositions can be worked up into the most varied articles. One of their applications is for covering walls, and for this purpose Billefeld's artificial wood is that mostly employed. Artificial wood presents the very great advantages of resisting the action of fire, of being a bad conductor of heat, and of not being attacked by vermin. Its hardness is equal to that of the hardest woods, it works well with tools, and can even be bent. On this account it has been recommended for making furniture, carriages, etc., and in such cases, to give it the power of resisting weather, it is soaked in a solution of asphaltum. A specimen of such artificial wood was examined by Dr. Sauerwein. It comes into commerce as slabs of about 20 inches square, and of different thicknesses. The thickest slabs had a glazed coating of a brownish-red colour on one side; three other kinds were without the glazing, but were coated with coarse linen. The grey, fibrous composition is fairly hard, so that it can only be cut with some difficulty; it cannot be bent far without fracture. Its strength

is about that of fir-wood cut across the grain, as it is ruptured by a strain of 640 to 650 lbs. per square inch, whilst the breaking strain of fir-wood cut across the grain is 550 to 850 lbs. It possesses a slight degree of flexibility, a strip 15 mm. wide, 7 mm. thick, and 13 inches long, supported at its ends and loaded in the middle, bending about 10 mm. before breaking. It softens when soaked in water, slowly if the water is cold, but very rapidly if hot. The filtered liquid gave on evaporation a residue which carbonised on heating, and gave with iodine the characteristic blue colour of starch paste, so that this substance was probably employed as a cement. Vegetable fibres consisting of refuse tow were easily recognised in the pulped mass. The material burned with difficulty, and without flame; it carbonised and finally left about 33 per cent. of ash, consisting of gypsum, alumina, ferric oxide, and silica. The brownish-yellow glaze contained chiefly ochre, clay, and a little glue.

Another composition consists likewise of large slabs, but only $\frac{1}{8}$ to $\frac{1}{6}$ inch thick. It is covered on both sides with coarse canvas, and cannot be bent, but breaks when this is attempted. It likewise softens in warm water, giving off a peculiar tarry odour, and the softened mass can also be recognised as made up of the refuse of tow. According to these results it appears to have been made from old rope and sails; hence its tarry odour. The water in which it has been soaked shows also the presence of starch. When heated it carbonises, and on complete combustion leaves about 40 per cent. of ash, consisting of silica, alumina, and ferric oxide, with some calcium sulphate. Clay or cement appears therefore to be one of its principal constituents, so it apparently consists of three main ingredients: 1, plant fibre, such as waste flax or hemp; 2, one or more mineral substances to which the mass owes its form and strength; 3, a binding material,

apparently starch paste. In preparing the material it seems to be a point of great importance to have the organic fibres sufficiently finely comminuted, in order that they may be the more intimately mixed with the other constituents, and that the composition should finally have been submitted to powerful pressure.

Attempts were made to imitate the material on the basis of the analysis, by mixing finely chopped tow, plaster of Paris, clay, sawdust, and starch paste. The plaster and clay were finely powdered, tempered with the paste and then mixed with the chopped tow and the sawdust, well kneaded together, and then quickly pressed in a hydraulic press. Equal parts of tow and plaster, with $\frac{1}{2}$ part of clay (or in another experiment $\frac{1}{2}$ part of porcelain cement instead of clay) gave, after drying, a very firm material, closely resembling the commercial one. The glaze was imitated by applying a mixture of ochre, cement, and glue solution. It is, of course, evident that this small-scale experiment is not absolutely conclusive as to the best materials and proportions for large-scale manufacture.

14. *Ribbach's Sawdust-composition for Coating Floor Boards, Table Tops, etc.*

Sawdust, or finely ground hard wood, powdered glass, quartz sand or fire-clay, zinc-white, and pigments, are intimately mixed (in proportions appropriate to the different objects for which the material is to be used), sifted, and then stirred up with linseed-oil varnish. The mixture is then spread, under pressure, on the surfaces to be coated, which have previously been cleaned and rubbed over with varnish, and is smoothed down. The surface may first be divided into compartments by fillets, and the compartments filled with differently coloured compositions. Such a flooring, after it has been well scrubbed with soap, can be waxed and polished.

15. *Wiederhold's Artificial Wood-composition.*

Wood-pulp, in the form in which it is supplied to paper-mills, is regarded by Wiederhold as a suitable material for making an artificial wood-composition. The simple compression to which this has been submitted confers on it a remarkable degree of hardness, which tends to render its employment difficult, since the wood-pulp cakes, once dried, are only with difficulty softened by soaking in water. The pressed wood-pulp acquires, however, a still greater degree of firmness when it is wetted with a weak glue solution. Wood-pulp takes the impression of the moulds accurately. The pressed articles, after drying, are coated with linseed-oil varnish, boiled to a thick consistence, and laid on boiling hot. By this treatment, which is repeated several times, the articles are rendered completely proof against the action of water; after drying they can be rubbed smooth and polished or painted, and then be varnished. Wood-pulp can be mordanted and dyed of any desired tint; the mordant must, of course, be applied before the linseed-oil varnish, or better still, before pressing into the moulds, though this is not absolutely necessary.

The employment of wood-pulp for the manufacture of moulded articles of the most varied kinds should prove more advantageous than the use of sawdust and blood, and solves the problem of the preparation of wooden articles by pressing into moulds, in a far simpler and more economical manner.

16. *Back and Potin's Artificial Wood.*

Back and Potin of Paris have invented a process for the manufacture of artificial wood, which yields very beautiful products, imitating very closely the different varieties of natural wood. This artificial wood consists of sawdust and glue, which, by treatment with either tannin or alum, has

been rendered insoluble in water when over-dry. In its original pulp form the product can be given any shape or impression, and the most practised eye cannot distinguish the moulded objects from actual carvings.

17. *Cohnfeld's Wood-composition.*

To obtain an artificial wood-composition, Cohnfeld moistens more or less finely subdivided refuse wood, straw, hay, leaves, bark, etc. (singly or mixed) with a solution of zinc chloride of about 1·028 specific gravity, and allows the zinc chloride to act on the raw material until it becomes dry. Thereupon follows a treatment with basic magnesium chloride solution, of specific gravity 1·725 to 1·793, after which the well-mixed composition is pressed into moulds. The composition is left under pressure for 10 to 12 hours, during which time it hardens in consequence of the heat which it develops. The objects are then allowed to dry for several days in a warm, airy place, and are then placed for 10 or 12 hours in a strong solution of zinc chloride, of specific gravity about 1·205, and are finally dried. This treatment is said to produce a material which can be worked just like a hard wood, viz., sawn, planed, bored, and polished, is fire- and waterproof, unattacked by weak acids or caustic lyes, and unaffected by changes of weather, and is therefore highly suitable for architectural or decorative use, with the advantage that it does not warp like wood, but retains its original form unchanged.

18. *Sciffarin* (*Wood-cement*).

is a mixture of sawdust, hemp fibre, starch-meal, gelatinous and mineral substances, the preparation of which is kept secret, and which has been used for the production of ornamental articles. This very strong and elastic composition is capable of taking a high polish.

CHAPTER VI.

EMPLOYMENT OF SAWDUST FOR EXPLOSIVES AND GUNPOWDER.

In the manufacture of explosives sawdust is used for three distinct purposes: (1) The sawdust is wetted with solutions of various salts, then dried and mixed with substances which, in contact with the salts absorbed by the sawdust, produce an explosive action. (2) It is used for absorbing nitroglycerine, both on account of its great capacity for taking up liquids and of the large quantity of gas developed by the combustion. (3) The wood-fibre is converted into pyroxyline by nitrating it with nitric acid, although for this purpose it is usual to employ a purer cellulose than sawdust. In all cases in which sawdust is used for absorbing a liquid it must first be strongly dried, as the presence of any moisture would detract from its absorptive capacity. When sawdust is to be nitrated it is generally first boiled repeatedly with solutions suitable for extracting from it, as far as possible, everything except the pure cellulose. These processes as well as the nitration are somewhat complicated and require special apparatus; their description lies beyond the limits of the present work, on which account I confine myself to the mere mention of some of the products, and a very brief notice of the methods of manufacture.

1. *Sawdust Blasting Powder.*

This explosive is made from nitrate of potash, nitrate of soda, chlorate of potash, sawdust, tan, and sulphur, and is prepared in the following manner:—

The nitrates of potash and soda and the chlorate of potash are dissolved together in boiling water in a pan. After boiling for 5 minutes the tan or sawdust, or the mixture of both, is thrown into the solution and thoroughly mixed. The mixture is transferred to a trough, mixed with flowers of sulphur and then dried. If tan is used it is either sifted and only the finer portions used, or else is ground. The blasting powder prepared by this process explodes violently, and is suitable for filling bore holes in rock where it is not possible to ram the powder down. This powder explodes by concussion, and on this account there should not be more than 25 per cent. of chlorate of potash present. To prepare a stronger powder, which will not explode on concussion, the two nitrates may be dissolved together without the chlorate; after absorbing this solution by sawdust, the boiling solution of the chlorate prepared apart is poured over the mixture, and the addition of sulphur, etc., proceeded with as before. To obtain a slower burning powder the chlorate may be mixed with the other materials as a fine powder instead of dissolving it. To obtain a weak powder the chlorate or the nitrate of potash, or both, may be omitted.

The proportions for 100 parts of the mixture are:—

30	parts	of water.
35	,,	of nitrate of soda (Chili saltpetre).
4	,,	nitrate of potash.
6	,,	chlorate of potash.
5	,,	sulphur.
23	,,	sawdust or tan.

Or,

30	parts	of water.
15	,,	nitrate of soda.
2	,,	nitrate of potash.
3	,,	chlorate of potash.
25	,,	sawdust or tan.

For the most energetic explosive the quantity of nitrate of soda is diminished and that of chlorate of potash increased,

adding the latter, either powdered or in solution, to the mixture of the nitrates with the tan.

Another formula which also gives a powerful explosive is :—

10 parts of nitrate of potash.
5 ,, nitrate of soda.

These are dissolved in warm water and the solution well mixed with 20 parts of sawdust; the mixture is then transferred to a tray, stirred up thoroughly with 5 parts of powdered chlorate of potash, and lastly 5 parts of flowers of sulphur are added and mixed in.

2. *Heraklin.*

This blasting powder has already been employed in Austrian and French coal mines: the gaseous products it yields are harmless, and it burns somewhat slowly, so that the rock is merely ripped down and not scattered about. According to the English patent of Dickerhoff (Vienna) 10 parts of sawdust, saturated with a solution of picric acid and saltpetre and dried, are mixed with 17½ parts of saltpetre and 7½ parts of sulphur. The solution for soaking the sawdust is made up of 1 part of picric acid and 1 part of saltpetre in 60 parts of water, for 30 parts of sawdust.

3. *Lignose.*

A blasting powder made of wood-fibre (sawdust, ground wood or cellulose) soaked in nitroglycerine is called lignose by Trützschler-Faltenstein; the wood-fibre serves in this case merely for the absorption of the nitroglycerine, instead of the infusorial earth usually employed.

4. *Robandi's Brise-rocs.*

This explosive consists of 40 parts of nitrate of potash, 20 parts of nitrate of soda, 15 parts of sulphur, 1 part of rock-salt, 5 parts of coal, 15 parts of woody substance (sawdust or tan).

5. *Carbazotine.*

The explosive known by the name of carbazotine consists of 50 to 60 parts of potassium-, sodium-, or calcium nitrate, 13 to 16 parts of tan or sawdust, 14 to 16 parts of sulphur and 9 to 18 parts of lampblack.

6. *Reynaud's Pyronome.*

For the preparation of this explosive 52½ parts of sodium nitrate are dissolved in the least possible quantity of hot water, 27½ of spent tan or sawdust and 20 parts of powdered sulphur are stirred in, and the mixture is dried with the necessary precautions.

7. *Poch's Poudrolith.*

A mixture is made of 3 parts of spent tan, 5 parts of sawdust, 3 parts of barium nitrate, 3 parts of sodium nitrate, 6 parts of wood-charcoal, 12 parts of sulphur, and 68 parts of potassium nitrate. The barium and sodium nitrates are first dissolved in hot water, the tan and sawdust are thrown into the solution, and the mixture thoroughly dried at a gentle heat. The dried mixture is powdered and the other constituents, also in fine powder, are intimately mixed with it in a rotating drum.

8. *Volkmann's Wood-powder.*

This powder is made by soaking sawdust in solutions of yellow prussiate of potash (potassium ferrocyanide) and saltpetre, the proportions of which may be varied, and then strongly drying the product.

9. *Köppel's Safe Blasting Powder.*

Two varieties of this blasting powder are manufactured: the first for hard, the second for soft rock. Their composition is as follows:—

	I.	II.
Potassium nitrate	35·00	42·00
Sodium nitrate	19·00	22·00
Refined sulphur	11·00	12·50
Sawdust	9·50	19·00
Potassium chlorate	9·50	—
Wood-charcoal	6·00	7·00
Sodium sulphate	4·25	5·00
Refined sugar	2·25	—
Picric acid	1·25	1·50
Potassium ferrocyanide	2·25	—

Each of the materials is pulverised alone and they are then mixed in a wooden drum. The mixture is moistened with 10 to 15 per cent. of water and stirred until somewhat large lumps are formed, which are then slowly dried and freed from dust by screening. The advantages of this blasting powder are its cheapness and its indifference to friction and concussion. It explodes only when brought in contact with burning or incandescent substances.

10. *Diorrexin.*

According to an analysis by Fels, the composition of this explosive is as follows :—

		In 100 parts of dry substance.
Picric acid	1·50	1·65
Wood-charcoal	6·82	7·49
Beech-wood sawdust	9·98	10·97
Potassium nitrate	38·93	42·78
Sodium nitrate	21·07	23·16
Sulphur	12·20	13·40
Water	9·00	—
Loss	0·50	0·55

Equal volumes of diorrexin and ordinary powder exert the same explosive force, but the fact that diorrexin is 25 per cent. lighter and costs $\frac{1}{5}$ less than black powder gives it the preference.

11. *Pyrolith.*

Wattlen gives the name pyrolith to a blasting powder of which he makes two kinds: one for hard rock, such as granite, etc., the other for soft rock, such as limestone, coal, etc.

The variety for hard rock consists of:—

12·5	parts of	sawdust.
67·5	,, ,,	potassium nitrate.
20·0	,, ,,	flowers of sulphur.

That for soft rock is composed of:—

11·0	parts of	sawdust.
50·5	,, ,,	potassium nitrate.
16·0	,, ,,	sodium nitrate.
1·5	,, ,,	powdered charcoal.
20·0	,, ,,	flowers of sulphur.

12. *New Dynamite No. III.*

Under this name a blasting powder is now manufactured which is a mixture of charcoal (or wood-meal), sodium nitrate, and sulphur, impregnated with nitroglycerine. According to Münch the percentage composition is 20 parts of nitroglycerine and 80 parts of a mixture consisting of 75 parts of sodium nitrate, 10 of sulphur and 12 of wood-meal. According to Göhl it contains 12·15 per cent. of nitroglycerine, 13·9 per cent. of sulphur, 56·4 per cent. of sodium nitrate, 13·86 per cent. of charcoal (or wood-meal), and 4·16 per cent. of water (inclusive of loss in analysis).

13. *Kellow and Short's Powder.*

The following formulæ are given:—

	I.	II.	III.
Potassium chlorate .	12 parts	6 parts	10 parts
Sodium nitrate . .	30 ,,	36 ,,	10 ,,
Potassium nitrate .	8 ,,	4 ,,	20 ,,
Sulphur	10 ,,	10 ,,	— ,,
Tan and sawdust . .	42 ,,	50 ,,	46

The tan and sawdust are soaked in a solution of the salts, the flowers of sulphur are then mixed in and the mixture is dried. According as the potassium chlorate is employed in the dissolved or solid state, and according as it is increased or decreased in proportion to the sodium nitrate, the powder develops more or less energy.

14. *De Tret's Blasting Powder.*

52·5 parts of sodium nitrate are dissolved in the requisite quantity of boiling water, and the solution is poured on to 27·5 parts of tan, which is thoroughly saturated therewith, 20 parts of flowers of sulphur being then mixed in. The mixture is dried and packed.

15. *Haloxylin.*

Most kinds of explosives contain sulphur; some, however, are made without that ingredient, as for example Fehleisen's haloxylin. It consists of :—

45 parts of saltpetre.
3 to 5 parts of wood-charcoal.
9 parts of sawdust.
1 part of potassium ferricyanide.

The sawdust, charcoal and saltpetre are intimately mixed, and to each 100 parts there is added a solution of potassium ferricyanide in 2 parts of water, to increase its explosive energy. The mass is then, like ordinary gunpowder, pressed, granulated, dried, and if necessary polished.

16. *Oller's Blasting Powder.*

Oller's blasting powder consists of :—

66 parts of potassium nitrate.
2½ ,, ,, potassium chlorate.
20 ,, ,, sulphur.
3½ ,, ,, wood-charcoal.
2 ,, ,, animal-charcoal.
6 ,, ,, sawdust.

17. *Terré and Mercadier's Blasting Powder.*

51½	parts	of	potassium nitrate.
16	,,	,,	sodium nitrate.
1½	,,	,,	coal.
11	,,	,,	sawdust.
20	,,	,,	sulphur.

18. *Schultze's White Gunpowder and Blasting Powder.*

Thin slices of wood are cut by a stamp into small cubical grains of the size of barley-groats. These are then boiled with dilute soda solution to remove the sap-constituents, then washed repeatedly, dried, submitted to the action of bleaching powder and again washed and dried. They are then nitrated with a mixture of nitric and sulphuric acids; the acid is removed by a centrifugal machine; the product is thoroughly washed and dried, then soaked in a solution of potassium or barium nitrate and again dried.

Schultze's powder has greater ballistic energy than common gunpowder, its smoke affects the organs of respiration less, it leaves a very small ash, and it can be stored and transported without the slightest danger, because it can be wetted and redried. Although higher in price than ordinary powder it is more economical in consequence of its greater efficiency.

19. *Dy's Yellow Gunpowder.*

This product differs from Schultze's only in the respect that, instead of wood-grains, the ground wood prepared for paper-making is nitrated after granulating. Sawdust may, of course, be used with the same result.

20. *Lannoy's White Powder.*

This is a mixture of coarsely powdered sulphur and saltpetre with addition of some form of pyroxyline such as nitrated wood, nitrated sawdust, or nitrated bran. It

dislodges the rock without any considerable shattering or scattering. It is difficult to ignite and burns slowly. In hard rock it is more effective than in coal or shale. It is costly to manufacture and gives a suffocating smoke, so that its freedom from danger is its only recommendation. According to analysis it contains 65 parts of sodium nitrate, 13 of sulphur, and 22 of wood-fibre.

21. *Lithofracteur.*

The name "lithofracteur" is used for certain blasting powders which consist of nitroglycerine absorbed by materials which are themselves explosive. When exploded they are converted almost wholly into gases of high temperature and pressure. The absorbing substances are prepared sawdust, coal, bran, etc., and the finished product contains 55 per cent. of nitroglycerine. The preparation of the sawdust consists in freeing it from resin and saturating it with saltpetre.

22. *Brain's Blasting Powder.*

consists of a mixture of potassium chlorate, potassium nitrate, wood-charcoal, and fine oak sawdust, 60 parts of this mixture being then caused to absorb 40 parts of nitroglycerine. Its explosive force is 25 to 30 per cent. higher than that of an equal weight of dynamite.

CHAPTER VII.

MANUFACTURE OF BRIQUETTES FROM SAWDUST.

Paper-pulp from Wood, and its Employment with Mortar, and as an Insulating Material.

Considering the relatively high heating value of sawdust, and the difficulty of burning it in the loose condition in ordinary fire grates, the obvious method suggests itself of bringing it into a compact form by the addition of some kind of binding material, and submitting it to high pressure, so that a handy, clean, compact fuel may be produced. The various binding agents: resin, tar, water-glass, Iceland moss, etc., which are used for making coal, coke, and charcoal briquettes, may also be used in this case, but as a rule the cost of converting sawdust into briquettes is too high to render any extensive use of the process possible. The conversion of sawdust into briquettes, both for burning into charcoal and for distillation, has, however, been adopted of late, and apparently with fairly good results.

One of the most important conditions for the formation of briquettes is that the sawdust must be as dry as possible, another condition being that comparatively powerful presses must be employed for the mixture of sawdust and binding material.

In pressing sawdust into briquettes, G. Grimm aims at obtaining a kind of felting of the material. A quantity of the sawdust sufficient to form a thin layer is first pressed into the mould; a further quantity is then added and the

pressure reapplied, and so on until the desired thickness is produced. By this method, in which each block is built up gradually from thin layers, a very perfect incorporation of the layers results from their mutual interpenetration, and the product possesses a degree of cohesion which renders it well fitted both for carriage and handling in general. Moreover, when the briquettes are used as fuel, a certain loosening of the layers is brought about by the heat, so that the whole mass is brought into a state of combustion more rapidly than would be the case if its contexture was uniform throughout. This property is also valuable when the briquettes are submitted to dry distillation, since the volatilisation of the products of distillation proceeds more rapidly and uniformly throughout the whole mass of the briquette than is the case with those prepared by other processes.

Amongst the newer processes for the manufacture of briquettes may be mentioned that in which the waste liquors from the manufacture of sulphide pulp is utilised. The sawdust—also small charcoal and charcoal powder—is mixed with the inspissated waste lye by a mixing machine, and very serviceable briquettes are obtained by pressing the mixture. The briquettes produced have a sightly appearance, are firm, coherent, and do not become damp as would have been expected from the hygroscopic character of the dry residue of the lye.

According to Meyer, waste or comminuted wood is steamed until its elasticity is destroyed, and the blocks obtained by pressing it are then submitted to distillation, whereby, it is stated, a very solid charcoal is obtained.

Pfropfe prepares briquettes from 2 parts of small wood and 1 part of tar, by shaping the mixture, either by hand presses or mechanical presses, into blocks or bricks, which are then distilled. The condensable products of distillation separate into aqueous and oily layers which separate

automatically. The residue in the retort is said to be pure charcoal.

Petroleum Briquettes with Sawdust.

Rosin is dissolved in petroleum by stirring or shaking; and during this operation, which takes about 40 minutes, finely powdered caustic soda, or another alkali, is gradually added. At the same time dry sawdust, or some similar absorbent material, is put in. The soda may be crushed under petroleum to prevent it from taking up moisture from the air. Powdered soda which has been slightly moistened with water may indeed be used, but the quantity of water must not be large enough to make the soda pasty. The operation is conducted in a receptacle furnished with stirring, or better with shaking, machinery. After thorough blending the mixture is removed from the receptacle and very soon becomes solid.

Sawdust Briquettes with Molasses.

Molasses is a very suitable binding material for the production of briquettes from sawdust, small charcoal, and charcoal powder. Saltercy describes his process, which can be employed for any combustible material, or even for ores, as follows: Experiments have shown that all kinds of sugar-molasses, whether dialysed or not, may be used for the purpose. The process is a very simple one. The sawdust, from which coarse fragments of wood should be removed, is dried until at least the greater part of the moisture is expelled, and then moistened with diluted molasses and thoroughly amalgamated in a mixing machine, such as is commonly employed for the manufacture of briquettes. The quantity of the binding material must be adjusted according to the dampness of the sawdust, only so much being added as will make the mixture feel moist. After the requisite blending

the powder is strongly compressed into moulds, and the bricks are allowed to dry for some time in airy situations before they are put to use.

Sawdust Briquettes for Distillation.

In order to use up wood waste most advantageously it is desirable to convert the loose, pulverulent material into a compact condition, and for this purpose the briquette form is the most appropriate and obvious. Amongst the newer processes which endeavour to solve the problem in this manner may be mentioned that of Bergmann, according to which the sawdust, after thorough drying, is merely compressed by strong hydraulic pressure into the form of solid briquettes. This proved impracticable, even with a pressure of 300 atmospheres (2 tons per square inch), without previous heating to 130° C. A new patent prescribes a pressure of 1000 to 1500 atmospheres ($6\frac{2}{3}$ to 10 tons per square inch), but it is obvious that the use of such enormous pressures is not only attended with many difficulties, high cost, and frequent repairs, but also with considerable danger and inconvenience.

F. Arnold of Magdeburg has constructed a toggle press, in which, by means of a steel lever, a very high pressure can be obtained with a relatively small expenditure of force, and with which both sawdust and shavings can be compressed into solid blocks, convenient either for burning or carbonisation.

According to a patent taken out by E. Leinhaas of Freiberg in Saxony (Ger. Pat. 86143) the preparation of such briquettes may be accomplished, without either high pressure or heat, by using the lime-sludge residue from the distillation of acetic acid as a binding material for sawdust.

Waste vegetable substances, sawdust, tan, etc., are air-dried and then mixed with the lime-sludge in simply con-

structed mixing machines. The mixture is made into briquettes by either screw presses, or other well-known briquette presses—the adoption of the special form of press depending on the daily output required—and is then carbonised in a special apparatus (Ger. Pat. 30338), the gases being passed through a chamber in which the briquettes were stacked up before the fire was lit, and working at first at a low temperature. The tar-vapours are precipitated on and are absorbed by the briquettes. The temperature is then gradually raised, whereupon the more volatile portion of the tar is driven off, whilst the heavier constituents of the tar carbonise in the interior of the briquettes and bind together the particles of wood. Simultaneously with the distillation products from the sawdust, etc., acetic acid is evolved from the lime-sludge, chiefly in the form of acetone. The gases are freed from acetic acid, acetone, tar, etc., by cooling, and the permanent gases are used for heating. The carbonisation is at an end as soon as the gases are found to be free from condensable products: and the time required is easily judged after some experience. The carbonised briquettes are somewhat cooled in the furnace, and are then transferred to air-tight cooling chambers. These charcoal briquettes form a far more valuable combustible than ordinary wood-charcoal, and furnish an incandescent fuel such as is required for heating railway carriages, flat irons, etc. Such a fuel was formerly obtained by powdering wood-charcoal, mixing it with soda, pressing into moulds and heating to redness. By the above process, however, the incandescent fuel is obtained direct at the first carbonisation, and the chief difference is the introduction of lime from the lime-sludge instead of soda.

Employment of Sawdust in the Ceramic Industry and as an Addition to Mortar.

The use of sawdust in the manufacture of pottery is owing to its property of lightening clay — the specific gravity of sawdust being very low—and of carbonizing or burning away completely to an ash during the subsequent firing, in consequence of which a further lightening, accompanied by porosity, is produced. It is, for instance, in this way that the Alkarazzas, those porous clay bottles formerly used by the Arabs for cooling water, which have continued in use in Spain and have lately been introduced into Germany, are made from clay with which fine sawdust has been mixed. During the baking of the vessels the sawdust is burnt off, and the clay is left with a multitude of minute pores, by which the water oozes through the walls. On the exterior of the vessel the water evaporates and, by rendering heat latent, keeps the contents cool.

In the same way porous plates are manufactured for drying substances containing much water, as, for example, starch. These plates are capable of absorbing much larger quantities of water than merely unglazed earthenware.

Bricks of greater or less porosity for building purposes can be obtained by the addition of a larger or smaller proportion of sawdust to the brick-earth. When such bricks are used for house walls, they produce far warmer rooms than common bricks, because the air in the pores is a worse conductor of heat than the clay. Moreover their weight is considerably less than that of ordinary bricks, and they can therefore be used for the construction of fireproof walls in situations where a heavy weight is inadmissible, or for building arches which will bear less heavily on their abutments. The use of such bricks is of high antiquity; in ancient Rome pumice was used in making them, but where that was not procurable clay was mixed

with substances which became consumed whilst the bricks were being burnt.

Sawdust is particularly suitable for this purpose, since the pores can be made larger or smaller according to the coarseness of the sawdust; moreover, it burns away at a low temperature, and leaves no detrimental residue, for the small amount of potash which the ash contains can have no injurious effect on the quality of the bricks.

A very modern product is the cement composition used for light partition walls, for plastering ceilings, etc. It is prepared by mixing cement or plaster of Paris with sawdust in various proportions, and casting the mixture to form planks, or mouldings, either with or without a reinforcement of wire netting. The use of sawdust as an addition to mortar for stuccoing the fronts of houses, etc., is well known, and such mortar finds various applications. For plastering walls and ceilings, and in damp rooms, Rohde employs a mortar composed of freshly slaked lime and the sawdust of soft wood, which should be in as fibrous a condition as possible. The quantity of lime should only be just large enough to render the mixture workable. This mortar forms a felt impregnated with lime, and is so light that, if struck, the injury does not extend beyond the spot on which the blow falls; whilst a coating of it which was laid on an extremely damp wall showed no change in solidity or in appearance in the course of eight years. Rohde specially recommends it for plastering mud walls and pisé work, as well as for roofs coated with clay. Even on the plank-walls of an ice-house, against which the ice was packed tight, a plaster coating of this material $\frac{2}{5}$ inch thick adhered firmly and remained sound. Rooms which have had their walls plastered with this composition can be papered in a few weeks.

Two American inventors have proposed to use sawdust instead of sand in stucco and wall plaster, in order to

lighten the mixture and secure firmer adhesion to the wall. An old practice was to use sawdust for covering up objects exposed to rain, cold, etc.; one of these patents proposes simply the use of a mixture of equal parts of sawdust and plaster of Paris or cement; the other gives the following :—

45 parts	of	a mixture of slaked lime and sawdust.
10 ,,	,,	plaster of Paris.
2½ ,,	,,	glue.
1 part	,,	glycerine.

Addition of Sawdust to Mortar.

By the use of sawdust the formation of cracks in wall plaster may be prevented, and on this subject the following statement has been made :—

"The house in which I dwell lies very high and exposed, so that the copious rain, which here, in the neighbourhood of the sea, falls almost continuously during the equinoxes, fills with water every chink in the outer cement on the weather side of the house, especially on the upper surfaces of the breast-mouldings and plinth-mouldings. These crevices are then gradually widened and extended by the formation of ice, so that in the spring large surfaces of the cement peel off. To remedy this inconvenience, which annually recurred in the same situations, and which was the more expensive and troublesome because the freshly stuccoed surfaces always required painting with oil, I had employed the most varied means without success, when the idea occurred to me to prevent the formation of crevices in the stucco by the addition of sawdust, which I expected to have a felting action similar to that of calf's hair. The sawdust was strongly dried, and then passed through a common fruit sieve to remove coarse chips, so that only the small woolly flocks were used. I made up the mortar with one part of cement, 2 parts of lime, 2 parts

of sawdust and 3 parts of sharp sand. The sawdust was first thoroughly mixed with the cement and sand and then the lime added. This had the desired result, for since that time no crack has shown itself even in those joints which were not bonded together, although, in the finishing cement-coat of these, sawdust could, of course, not be used." Sawdust therefore fulfils the purpose of matting a plaster, so as to prevent it from cracking, far better than hair, and in such cases as the foregoing is strongly to be recommended.

Quite recently a commencement has been made in the use of sawdust as a non-conductor of heat, by mixing it with plaster of Paris, loam, mortar, hair, cork, etc., and applying a thick layer to steam pipes, cylinders, heaters, etc., round which cloth has first been wrapped, and giving it a coat of oil paint when dry.

Stony Composition from Sawdust for a Building and Insulating Material.

This invention relates to a stony composition which should be particularly suitable as a building material for the construction of walls and flooring, for making rooms damp-proof, for pavingstones, for building reservoirs and for vessels of every kind. It consists principally of wood-meal and plaster of Paris, or cement. The wood-meal requires to be so prepared that it will unite intimately with the plaster or cement; it also needs to be made incombustible and prevented from absorbing moisture. The proportions used are: 2 parts of wood-meal to 1 part of plaster or cement.

The wood-meal requires boiling for a long time with water-glass, powdered asbestos, and a little glue or other binding material, in order that the fine particles may be thoroughly penetrated by the water-glass, and coated with

the asbestos. Thus prepared, the meal is not only incombustible and non-hygroscopic, but, as already mentioned, is particularly capable of uniting with plaster of Paris to a homogeneous mass of great hardness, such as has not hitherto been obtained with wood-meal.

The prepared wood-meal is mixed with plaster or cement and water and is poured into a mould, in which, if desired, wire netting can previously have been placed. For purposes where maximum strength of material is desirable, the contents of the mould may be exposed to pressure whilst hardening.

After the mixture has hardened, the slabs or other objects are baked in a kiln, or are dried in a stove specially constructed for the purpose.

According to the uses to which the product is to be put, sand, tar, asphalt, and other substances may be added to the wood-meal after the boiling with water-glass.

The material obtained by this process is light and of low porosity; it has the great advantage of not being hygroscopic or permeable to moisture. Walls built of this material may have nails driven into them without any damage to the surrounding parts, whilst the nails hold well on account of the firmness of the substance. Moreover, in consequence of the treatment of the wood-meal with water-glass and asbestos powder, the material is fireproof. The addition of tar acts also as a protection against vermin, rotting, and the growth of mould.

The hardness of the substance and the other properties mentioned render this material peculiarly fit for paving-stones. It lasts well, deadens sound, and does not wear out the horses' hoofs.

This material is also a low conductor of electricity, and is therefore suitable for use as an insulator.

In comparison with the well-known practice of coating wood with water-glass to secure a better adhesion of

plaster, it should be borne in mind that, in the new process, each particle of the wood is thoroughly saturated with water-glass by the process of boiling the sawdust in a solution of that substance.

Manufacture of Paper-pulp from Wood (Sawdust, Shavings, etc.) for Paper-making.

In the employment of wood for paper-making the endeavour is to obtain a cellulose as pure and as long fibred as possible ; sawdust, however, furnishes only very short fibres, and is moreover so bulky that the boiling, or at least the circulation of the liquid in the boiler, is much impeded.

The apparatus described below is intended to overcome this difficulty and to render possible the production of a serviceable wood-pulp from sawdust, shavings, and waste pieces of wood 2 to 3 inches thick, by a combined boiling and grinding process. The apparatus represented in vertical section in Fig. 42, and in horizontal section through the line *a*, *a*, by Fig. 43, consists of a steam-tight cylinder, A, which has a smooth inner surface and in which there rotates a central axle, H, carrying a number of forked plates, *d*, *d*. The forks are provided with adjustable journals, which are connected with the adjusting screws, N, N, by springs. In these journals revolve the axles, P, of the rollers, K, which the rotation of the shaft H causes to roll round on the inner surface of the cylinder, A, and to exert upon that surface a greater or smaller pressure according to the centrifugal force developed by a higher or lower speed of rotation.

Instead of the bearings with springs, the construction shown in Fig. 44 may be adopted. Here the rollers, K, are bored out and ride loosely on the axles, P, fixed to the arms, J, so that they press against the interior of

the cylinder, A, solely by virtue of the centrifugal force developed by the rotation, and in doing so take up a more or less eccentric position with regard to the axles, P. The process is as follows: Through a manhole in the cover of the cylinder an appropriate quantity of sawdust, shavings, or wood-chips is introduced, water being added in quantity sufficient to float the charge of wood. The manhole is closed, and through the tangential pipe, T, steam is admitted at a pressure of at least 52 to 53 lbs. per square inch.

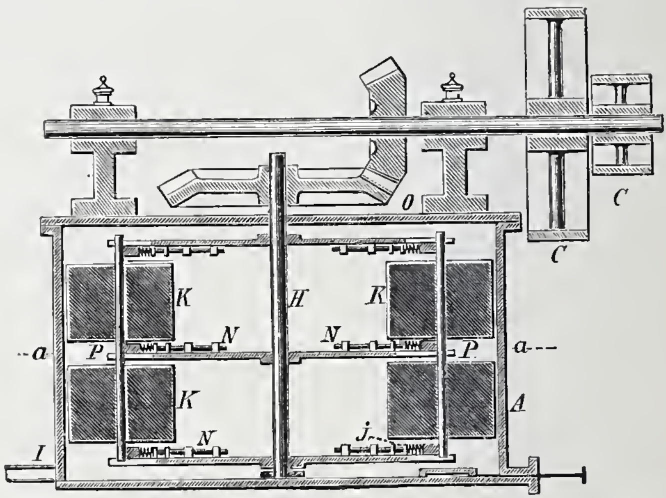

FIG. 42.—Apparatus for Preparing Paper-pulp from Wood Waste (Vertical Section).

The steam throws the mixture into rotation, heats it up, and produces a pressure in the cylinder. This treatment causes the fibres to acquire a degree of tenacity which prevents them from breaking off short during the subsequent action of the rollers. Some lime, soda, or potash may be added to the mass at the outset, to render the fibres more pliant and free them from all impurities. The mass remains exposed to the action of the steam until the fibres have acquired the requisite toughness and

pliancy. This generally takes two hours, after which for another two hours the mass is gently worked with the rollers. The main shaft, which drives the axle, H, by bevelled gearing, is fitted with pulleys of two sizes, C, C, to

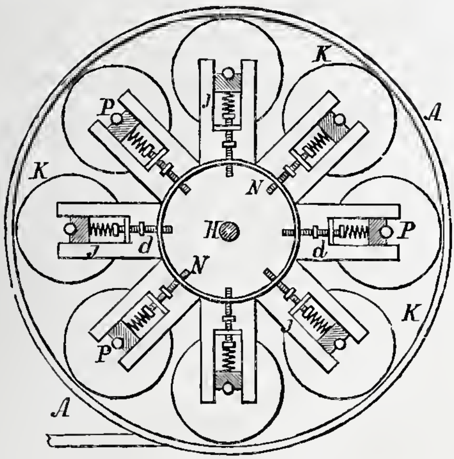

FIG. 43.—Apparatus for Preparing Paper-pulp from Wood Waste (Section through the line a, a).

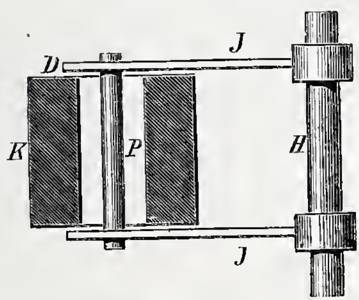

FIG. 44.—Modified Apparatus for Preparing Paper-pulp from Wood Waste.

give two different speeds. By running the shaft with the large pulley, a slow speed and light pressure on the interior of the cylinder are obtained. The rollers are arranged so as to bear upon almost the whole surface of the cylinder.

Either a single long roller, or several superposed short ones may be employed. By reason of the yielding of the springs, the rollers are able to pass over any hard portions of the material without injury to the machinery. After the machine has been driven for two hours at a slow speed, the driving-belt is shifted to the small pulley and the rollers are set in rapid rotation. This throws the wood outwards towards the walls of the cylinder, where the fragments become progressively crushed and disintegrated, without, however, any breaking up of the fibres themselves; and, as the pressure of the rollers on the cylinder is considerable, and the fragments of wood pass under them again and again, the individual fibres are at last completely separated one from another. The process may be conducted without the addition of any alkali, the action of the steam being relied on to produce the requisite toughening of the fibres. In that case, however, the operation requires a much longer time.

Kapp's Wood-pulp.

The wood-pulp obtained when wood is ground by millstones with addition of water is essentially different from cellulose. It is merely wood reduced to a fine state of subdivision, the fibres being still coated with the incrusting substance, and may be used as an addition to paper-pulp and rags in making common pasteboard. To grind waste wood and tan (but not sawdust) to wood-pulp, W. Kapp of Berk-on-the-Lippe uses a stone mill with horizontal rolls, above which is fixed a feeding-box fitted with plungers. The material to be ground is filled into the box, below the plungers, the latter being meanwhile raised by a hand-wheel engaging in a pair of racks, which when raised are fixed by a ratchet. When the ratchet is released the plungers are depressed by a counterpoise. The lower

edges of the feed-box should not actually touch the stones, but the intermediate space must be as small as possible: should it become increased by wear, the position of the box may be adjusted by means of screws, even while the machine is running. To prevent the wood-pulp from flowing over the ends of the stone rollers, wooden cheek-blocks are fitted close to the stones. Whereas, in ordinary mills, the use of hard stone is inadmissible, since such stone would produce an inelastic, brittle material, in Kapp's machine it is advantageous, the disintegration process being different, because the material has already been partly reduced in size; and much finer fibre is produced.

The stone requires to have a peripheral velocity of about 1640 per minute. The water required is supplied by a pipe as in an ordinary wood-pulping mill.

CHAPTER VIII.

VARIOUS APPLICATIONS OF SAWDUST AND WOOD-REFUSE.

Sawdust as a Material for Preventing Rough Cast from Flaking off under the Influence of Frost and Rain.

Sawdust should serve very much better for this purpose than the hair commonly employed. It must first be well dried, and sifted to remove all coarse particles. A mixture is then made with 2 parts of sawdust, 5 parts of sharp sand, and 1 part of cement, which are thoroughly commingled, 2 parts of lime being then added.

Manufacture of Casks from the Waste-wood of Saw-mills.

The outside planks of tree trunks, which are obtained as a refuse product when cutting the timber into deals, are cut lengthways by an ordinary circular saw, and each of the pieces is reduced to the length required for the cask staves. Each of these pieces is again cut to the proper width by a multiple circular saw, to which the wood is fed by means of grooved rollers. Lastly, a circular saw, with vertical spindle and automatic feed, cuts the pieces to the size required for the staves. This saw has a diameter of about 23½ inches. In the middle of the spindle, above the saw-bench, there is a guide rod, at each side of which a grooved feed-roller is situated, by this arrangement

enabling two pieces of different thickness to be cut simultaneously. These pieces are then conveyed to the trimming and chine-cutting machines, in order to have their ends cut to the right bevel and the chine notches cut out for the reception of the cask heads. This machine has a shaft carrying the knives for cutting the chine notches, and two shafts for the trimming saws. Both the trimming saw and the notching knives can be set to the proper distance apart for staves of any required length.

The staves are fed into the machine by hand, each stave being laid with its rear edge on a rod which moves backwards and forwards in guides. The pieces so trimmed are now conveyed to the jointing saw, a machine with a small, strong circular saw, to which the pieces are brought upon a carriage which runs on rails. This machine gives the edges of the stave their exact bevel, no hand work being afterwards required to fit them together. To save freights, the casks are not made up, the staves and heads for each cask being tied into a bundle. The heads are cut out in the same fashion from shorter waste pieces, and from pieces not suitable for staves. The head pieces are dowelled and cut to the circular form by a special machine. All the machines can be fed by boys. One set of machines will turn out several hundred casks a day. The demand for these is almost unlimited, since the users of such casks —cement makers, millers, nail makers, and fruit merchants —are always ready buyers.

Manufacture of Calcium Carbide from Sawdust.

For the manufacture of calcium carbide, from which acetylene gas is prepared, by the action of water, either coke, coal, or wood-charcoal may be used. According to a patent obtained by Wilson of Ontario, the charcoal of sawdust and other wood-refuse can be employed. These sub-

stances are carbonised by heating in suitable furnaces, and the finely powdered charcoal is mixed with limestone. The mixture is then exposed for 10 hours to the heat of an electric arc which is sufficiently powerful to melt iron and boil lead. The product is calcium carbide, which, reduced to small fragments, is supplied to consumers in this form in tin canisters.

Sawdust as Manure.

Sawdust, by itself, has but little value as a manure, because it is non-nitrogenous, and even when decomposed in the soil by atmospheric influence is incapable of furnishing any nitrogenous materials to vegetation. Though its value as a manure is far less than that of straw, it would be incorrect to regard it as altogether valueless. For although the amount of phosphoric acid and potash in the wood of coniferous trees is extremely small, nevertheless, in the soil, sawdust is rapidly converted into humus which, for many varieties of soil, has at least some value. On the other hand, however, it must be remembered that the pure wood-fibre such as is present in wood-meal is a particularly stable substance, very indisposed to rot spontaneously, and therefore decomposes so slowly that the carbonic acid it generates is supplied far too gradually to have any marked effect on the vegetation with which it is in contact. If therefore we disregard its mechanical effect, its manurial value is almost nothing. Its mechanical action, especially its great capacity for absorbing liquids, is however so considerable, that, from this point of view alone, it deserves notice, and as a matter of fact, sawdust is largely used as a mulch. The practice, therefore, which has been frequently recommended, of mixing artificial manures with long-fibred, woolly sawdust, and throwing the mixture into heaps to undergo fermentation, is by no means to be rejected. One of the great

advantages of this method is that the powdery manure when applied at a particular spot does not get blown all over the place; moreover, the decomposing sawdust ought to render the manure more soluble and more rapidly active.

1. *Richardson's Artificial Manure.*

For the preparation of his artificial manure, Richardson employs dry sifted sawdust, which he moistens with hydrochloric or sulphuric acid and then heats to 130° F. The mixture is either spread on the land as it is, or is mixed with blood and heated to 140° F., which causes the blood to coagulate. The dry mixture can be packed in sacks, distributed to consumers, and used as manure. Instead of blood, bone-ash, coprolites, animal charcoal, or natural phosphatic minerals, such as phosphorite, etc., may be added to the mixture of sawdust and sulphuric acid. The mixture is thrown into heaps which are then covered with straw, old sacks, etc., whereupon, by chemical action, a heat of 100° to 150° F. is developed inside the heaps. When the temperature of the heaps has fallen to that of the surrounding atmosphere the process may be regarded as completed and the product be put to use.

2. *Carbonised Sawdust as Manure.*

To employ sawdust in agriculture it is most advantageous that it should be carbonised. With this object charcoal heaps are constructed of brushwood, such as broom and other dwarf shrubs, and gradually filled up with sawdust, which is thrown on lightly with the shovel in such a way as to leave numerous gaps for the admission of air. When the heap is covered with a layer of sawdust, which must not be too thick, the fire is kindled. Wherever the fire begins to break through, more sawdust is thrown on, and when the layer has reached a certain

thickness the heap is allowed to cool. After complete cooling the heap is taken apart. The charcoal obtained in this way is mixed with liquid manure, urine, phosphates, blood, etc., piled up in heaps, and left to itself for some weeks. The sawdust must of course be dried before being carbonised, and the operation must be carried on in a dry locality. This manure has given excellent results with a variety of plants.

3. *Manure from Tan.*

1. The production of the manure depends on fermentation, and for the formation of the compost heap it is desirable to select a place exposed to air and moisture. On the spot selected, a layer of tan about 14 inches thick is spread out, and covered with 2½ inches of slaked lime: above this a second layer of tan is spread, and likewise covered with lime, and the heap is built up in this way with alternate layers to a height of about 6½ feet. The heap is moistened with water until it heats strongly, and the bark, which, on account of the tannin it contains, does not readily rot by itself, is brought by the lime into a decomposed condition. If it is desired to obtain a strongly forcing manure, a layer of powdered gypsum (Terra alba) is spread upon the lime, then one of fresh, undecomposed horse dung, then tan again, and so on to the desired height. Liquid manure and urine are then poured into holes made by thrusting a stake into the heap, and the whole is left to rot.

2. The following mixture also gives an admirable compost: 10 parts of well-manured garden soil, 2 parts of gypsum, 1 part of quick-lime, ¼ part of rock-salt, 2 parts of wood-ash, 1 part of tan. The whole is well mixed, and laid out in a long ridged heap. Whilst mixing, strong liquid manure (drainage from the dung heap) is added as

long as it can be absorbed without causing the mixture to cling together. The heap is turned over and moistened with liquid manure twice a week for a month. It is necessary that it should heat up if it is to prove an efficient forcing manure. The heating is due to the tan. If tan is not obtainable, the dust or refuse from threshing clover seed, rye, wheat, or buck-wheat may be used instead; also malt dust, fir sawdust, etc., may be taken. The heap will begin to heat within 24 hours, and if turned over regularly and moistened twice a week it will be fit for use in a month..

Wood-mosaic Plaques from Wood-shavings.

The curled shavings obtained in planing wood are flattened out by hand, after soaking in water or steaming, being laid one on the other and gently pressed for some time. They thus become perfectly flat and can be easily and rapidly piled up in regular layers, after being first dipped in thin glue. Care must be taken that the heaps are built up perpendicularly, with which object the thin and thick parts of the shavings are alternated. The block thus obtained should be pressed until the glue is perfectly dry, and will then form a solid mass, the thickness of which depends on the width of the shavings, and its other dimensions on the length and number of the shavings employed.

These blocks can be planed smooth on the surfaces which exhibit the edges of the shavings, and several of them can then be glued together. The planed surfaces have a very agreeable appearance, and enable mosaic patterns of a very special character to be constructed. With this object the shavings are dyed with various colours before they are glued together, care being taken that the dye penetrates the shavings thoroughly; and

then after being dipped in glue, the differently coloured shavings are alternated when superposing them one on another.

By this process very pretty wood-mosaics can be produced, which show fine, variously coloured veins, and are specially suited for inlaid work and for many other purposes.

Bottle Stoppers Made from Wood-Shavings.

These can be prepared as follows: The shavings are wound round a short cylindrical rod of wood, both the rod and the shavings, as well as the exterior of the composite plug, being smeared with a resinous or caoutchouc cement. The rod should be of the same length as the width of the shavings, and should have a solid handle by which the stopper can be drawn from the neck of the bottle or jar.

The stoppers are finally immersed for half their length in melted paraffin wax, and are then ready for use.

Employment of Waste Wood from Saw-mills for Parquetry.

Parquetry blocks are generally either 23 or 25 inches square. Nowadays, the base blocks for veneered parquetry are prepared as follows: Pieces somewhat shorter than the block to be made are glued together, cut to size, and fillet pieces attached to their ends by grooving and tonguing. In Russia a special method is in use. The base block is formed of a frame, two cross rails, and four panels, and the frames are furnished with holes and dowels by which they are fitted together. The four panels are tongued and grooved into the rails and frame, and only the dowels require to be glued. The panels are so arranged that the grain of one runs at

right angles to that of the other. This renders any warping of the block impossible, and the shrinkage is reduced to a minimum, since only the two frame pieces, which lie parallel to one another and have a total width of not more than 10 inches, are capable, even under the most unfavourable variations of temperature, of slightly swelling or shrinking. Any waste pieces of wood may be used for making these base blocks, as the panels are at most about 8 inches long. By using a circular saw and a simple drill for boring the holes, these blocks can be made with the greatest ease.

Wooden roof-shingles are still saleable articles, and are easily and cheaply cut out with a circular saw.

Fire-lighters from Sawdust and Shavings.

Fire lighters, which can be used for rapidly kindling any kind of fuel, are made from sawdust or shavings impregnated with rosin. The sawdust-lighters are made by melting the rosin (the cheapest, darkest quality) in an iron pot, adding the requisite quantity of sawdust gradually, and thoroughly mixing it with an iron rabble. The sawdust must first be thoroughly dried or the rosin will froth up too much. The mixture is next spread out on a moulding bench which has been well oiled, and a well-greased roller is passed over the mass and presses the mixture into the furrows in the bench whilst at the same time reducing it to the proper thickness. The individual fire-lighters can then be separated from one another, by breaking the mass at the indentations, and be packed and sent to market.

Fire-lighters of another kind consist of shavings, which are unrolled, dipped into melted rosin, and rolled up again.

Manufacture of Carborundum from Sawdust.

Carborundum is prepared by fusing in the electrical furnace a mixture of coke and sand, to which a little common salt is added to increase its conductivity, and some sawdust to render it porous and furnish an outlet for the gas evolved (carbon monoxide), thus preventing explosions.

The dimensions of the furnaces are 106 by $22\frac{1}{2}$ by $22\frac{1}{2}$ inches.

The older practice was to establish an arc between the poles; at the present time a cylindrical rod made of coke-powder is laid between them, and this being a bad conductor is raised by the current to an intense white-heat, which enables the process to be conducted much more economically. The production of 1 lb. of carborundum requires at the present time about $6\frac{1}{2}$ horse-power. The current supplied by the Niagara Falls Power Co. has a tension of 2200 volts, and is stepped down to one of 185 volts by a transformer, which was the largest in the world before the installation of the one at Buffalo. The efficiency of the transformer is 96 per cent., therefore out of each 1000 horse-power 40 are converted into heat, so that ample cooling appliances have to be provided. The thick oil with which the transformer is filled is cooled by a spiral water pipe, and is kept in constant circulation by a pump.

The course of an operation is thus described in the Journal of the Franklin Institute: During the first half-hour after charging the furnace and turning on the current, nothing is to be observed; a peculiar odour is then developed, and the gas which escapes through the crevices in the furnace can be kindled. After three to four hours the walls and the upper part of the furnace are completely surrounded by the light-blue flame of the carbon monoxide produced from the coke and the oxygen of the sand. After

four or five hours the crown of the furnace begins to sink in, and cracks open through which yellow sodium flames escape. It frequently happens that the uppermost layer is not sufficiently porous to allow the carbon monoxide to escape freely: a rent is then formed suddenly, a puff of burning gas escapes, and a small crater is instantaneously formed which throws out white-hot ashes, a blinding yellow flame, and a thick smoke which fills the whole workshop. In such cases it is often necessary to shut off the current and allow the furnace to cool slowly, so that the faulty part can be removed later on and filled up afresh. After 24 hours the current is shut off, and the charge of the furnace is cleared out down to the amorphous outer layer of carborundum. This fritted crust, which surrounds the core, is broken away, and the crystallised carborundum is found inside. This is reduced to powder of different degrees of fineness by levigation, much in the same way as emery. Its price is from two to five times that of emery, but it is lighter and therefore goes farther. The Carborundum Co. maintain that their product does its work more quickly and neatly than emery.

CHAPTER IX.

THE PRODUCTION OF WOOD-WOOL.

UTILISATION OF BIRCH BARK.

In large saw-mills, carpentry and cabinet-making workshops, etc., a large amount of wood-refuse accumulates for which no immediate use can be found, and which in many cases is simply burnt. Any of these waste pieces not measuring more than $16\frac{1}{2}$ by $5\frac{3}{4}$ inches may be very advantageously worked up for wood-wool. Wood-wool consists of filaments of various degrees of fineness, and with a correspondingly higher or lower elasticity. In the comparatively short time that has elapsed since it was introduced this material has already found extensive employment.

Wood-wool is a clean, dust-free, light, and very elastic packing material, and compared with straw, hay, etc., has the advantage of not rotting so readily. Being specifically lighter than any other packing material, the quantity required is about 30 to 40 per cent. less. It is specially suitable for packing glass, porcelain, fancy goods, hardware, metal ware, perfumery, drugs, and medical preparations (in glass, and other vessels), and also for meat, sausages, fruit, eggs, flowers, etc.

Wood-wool is employed in metal foundries for wrapping round the loam moulds; it is also a very serviceable stable litter where straw is unobtainable, and is much to be preferred to either leaves orpine needles.

Wood-wool is used with advantage for stuffing cushions,

and retains its elasticity far better and longer than sea-weed, hair, etc. The resin contained in the pine- and fir-woods, which are almost exclusively employed, protects the articles which are stuffed with wood-wool from the attack of insects; moisture also has but small effect on this stuffing material. The investigations made by the Prussian War Office have shown that pine-wood fibre is a very agreeable, soft, and clean material for stuffing mattresses for hospitals and barracks, is highly appreciated by the sick and free from all the disadvantages which have hitherto been unavoidable.

Very fine wood-wool has quite recently been employed for surgical dressings, for which it has been found highly suitable. It also answers the purpose of a flesh brush, as it opens the pores of the skin and freshens and invigorates the surface. The very finest, the so-called lint-wool, is used in hospitals and infirmaries. The shavings produced by wood-wool machines serve also as a filtering material, for making vinegar, and for fire-kindlings: those made from hazel-wood are used in breweries; beech-wood shavings in vinegar factories; and pine-wood shavings for fire kindlings. Wood-wool is also used instead of cotton-waste for cleaning machinery, as it is considerably cheaper, and is far less liable to spontaneous combustion.

The machines employed for producing wood-wool will turn it out in a coarser or finer condition. The product may be dyed any colour by simply immersing it in a dye-bath, draining it on sieves and drying. Various colours may be obtained by the following formulæ:—

1. *Brown.*

Three parts of permanganate of potash are dissolved in 200 parts of cold distilled water, the wood-wool being immersed in the solution for a few minutes and then taken out.

2. *Yellow.*

Five parts of ground turmeric root are boiled with 150 parts of water and $\frac{1}{2}$ part of alum; the decoction is strained from the powder through a sieve and is then ready for use.

3. *Green.*

Two parts of soluble aniline green are dissolved in 250 parts of water.

4. *Blue.*

Two parts of soluble aniline blue are dissolved in 200 parts of water.

5. *Red.*

Two parts of soluble aniline red (eosin, ponceau, or rosein, according to the shade desired) are dissolved in 250 parts of water.

6. *Violet.*

Two parts of aniline violet are dissolved in 250 parts of water.

The best mode of procedure is to put the wood-wool in a large sieve, dip the whole into the dye-bath, then take it out and allow it to drain, after which the dyed wool is dried on wicker racks in a moderately heated chamber.

One of the best wood-wool machines is that of Anthon & Sons of Flensburg: it can be made double, triple, or quadruple acting. In the double-acting machines the carriage has no movable parts. These double-acting machines are employed wherever quantity rather than quality is required in the product, the reason for this distinction being that no piece of wood can be planed equally well in both directions, as any one can ascertain by trying the experiment with a hand plane, when it will be found that whilst cutting against the grain the shavings are not so smooth as those cut in the opposite direction. For coarse

wood-wool this is of no consequence; but if, on the other hand, the object is to produce extra fine and delicate wool, such as the patent carriage of the machine is intended to yield, it is necessary that the machine should be single-acting, each piece of wood being introduced between the feed-rollers in the right direction for planing with the grain. A special advantage of this machine is that filaments of various widths can be obtained from it without the necessity of changing the slitting knives.

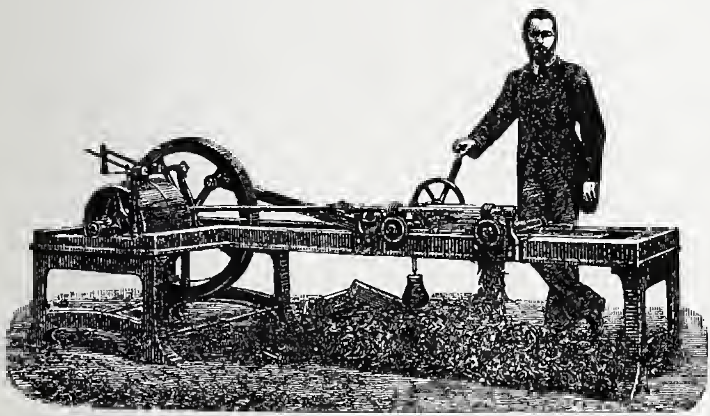

Fig. 45.—Double Acting Wood-wool Machine (Anthon & Sons).

The whole machine (Fig. 45) is supported on a solid iron frame, which as a rule is arranged horizontally, being furnished with iron legs as shown in the figure. It can, however, where space considerations or the driving arrangements require, be set up in a sloping position. The frame carries the driving-shaft with fast and loose pulleys, a crank and fly-wheel. By means of a connecting rod, the crank imparts a reciprocating motion to an iron carriage, which latter carries the very simple cutters, one or sometimes two broad plane irons, and a series of pointed knives, which are set to the required width of the fila-

ments, and which produce longitudinal cuts in the wood, whilst the plane which follows them takes off a shaving from the already scored surface, and the resulting wood-wool falls from the machine. Two toothed rollers arranged transversely across the carriage, and revolving to a certain distance backwards for each movement of the latter, hold the wood which is to be planed, the roller nearest the crank being pressed against the wood by a rack and pinion acted on by a weight hanging from a cord which passes over a pulley, and thus bringing the wood up to the plane through a definite distance at each cut. A lever connected with the pulley permits a more rapid to-and-fro motion of the pulley, and consequently a rapid backwards and forwards motion of the front roller, so that pieces of wood of different lengths can be introduced under the rollers one after another without stopping the machine.

The machine can easily be attended by a single workman, who, after throwing the driving belt upon the driving-pulley has merely to thrust one piece of wood after another between the rollers; this is done with the left hand, whilst the right hand moves the front roller nearer to or farther from the back roller, according to the length of the pieces.

When the rollers have seized the piece of wood it is unnecessary for it to be held by the hand any longer: the rollers push it forward automatically, so that, unless the pieces are very small, one workman can easily feed two machines. The machine has a length of 10½ feet and a breadth of 3 feet 4 inches. The driving-pulley is 20 inches in diameter by 6 inches broad, and should make about 150 revolutions per minute. The output of a double-acting machine should amount, in 10 hours, to 6 to 12 cwt. of the coarsest wood-wool, according to the kind of wood: of finer wool a proportionally smaller quantity is produced. The thickness of the filaments is always the same; but

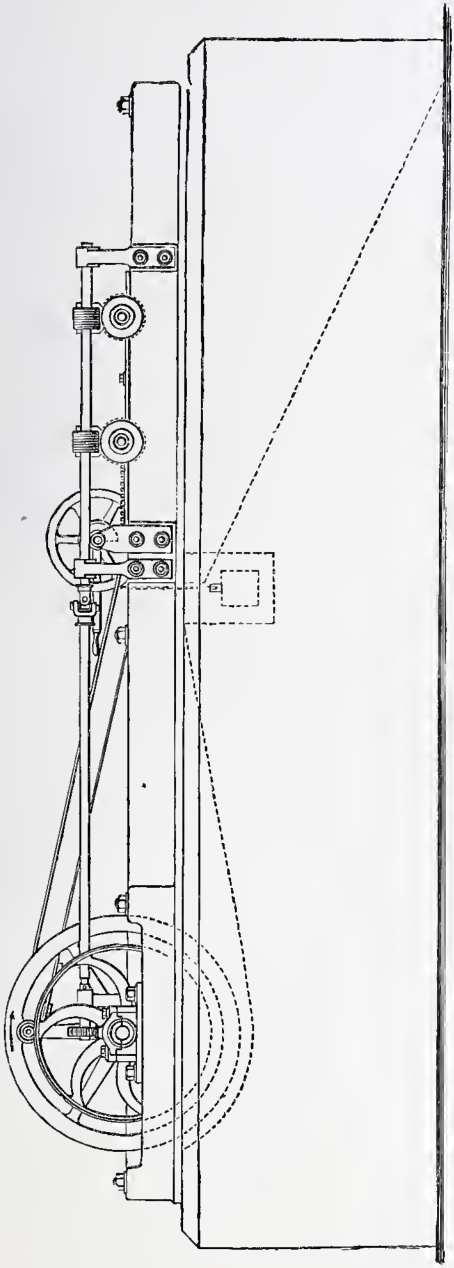

Fig. 46.—Wood-wool Machine (Front View).

if desired, different worm-wheels can be supplied at an extra cost, giving a variety of thicknesses, the most usual being 3, 5, 15, and 20 filaments to 1 millimetre. The width of the filaments can be regulated by either clamping the scoring knives close together, or by inserting distance pieces of any desired thickness between them. The power required for a wood-wool machine is 1 to 2 horse-power according to the yield.

The machine will take round, square, or flat pieces of wood of the following maximum dimensions; about 20 inches long by $5\frac{3}{4}$ inches wide, and, of course, pieces which are smaller in either direction. The thickness is not restricted, but it is nevertheless disadvantageous for it to exceed 20 inches. The material can be worked down to pieces of 1 inch in square section; the waste is therefore very small.

The machine can be driven equally well by wind, water, steam, or any other power, and is capable of reducing cane to wool. It is not clear, however, that there is any advantage in working up cane into wool, for new cane is too costly and short thin pieces of waste cane are not profitable because the yield is so small, and the wool would be very irregular. Trials have also proved that though cane in rods is elastic, the wool it yields possesses no greater elasticity than that from beech, oak, and other soft woods.

Another construction is so distinctly shown in elevation and plan in Figs. 46 and 47 as to require no further explanation. The length of the machine is about $10\frac{1}{2}$ feet, its breadth $5\frac{1}{4}$ feet; the diameter of the driving-pulley is 20 inches and its width 6 inches; and the weight of the whole machine is about 12 cwt. For 150 revolutions per minute it requires 1 to 2 horse-power, and in 10 working hours will turn out 5 to 9 cwt. of wood-wool.

The improved quadruple-acting wood-wool machine of Anthon & Sons consists of a very strong frame, which is

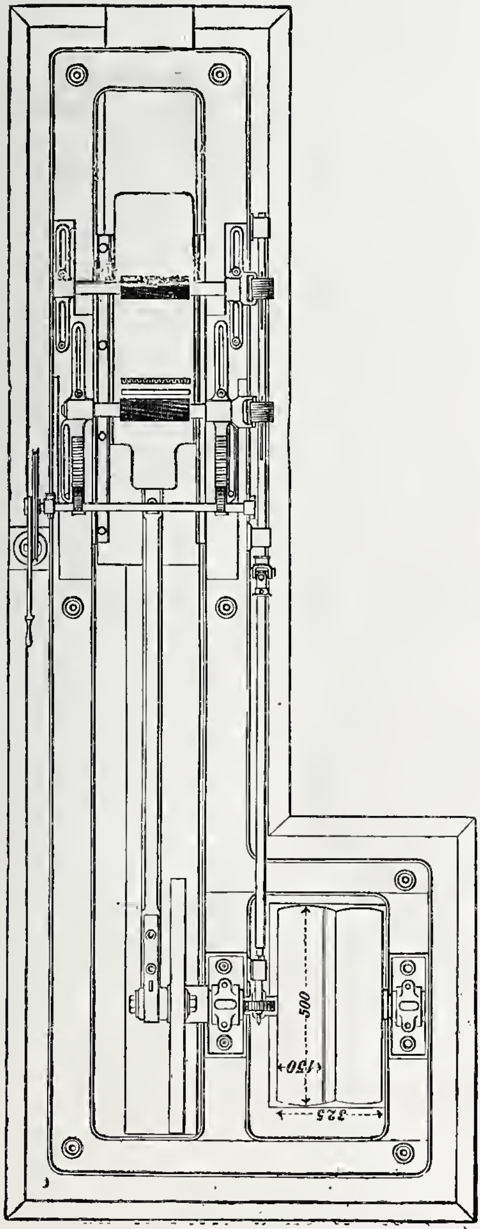

FIG. 47.—Wood-wool Machine (Plan).

set on a brick foundation, or in cases where a brick foundation cannot be used, a strong wooden frame, or a cast-iron

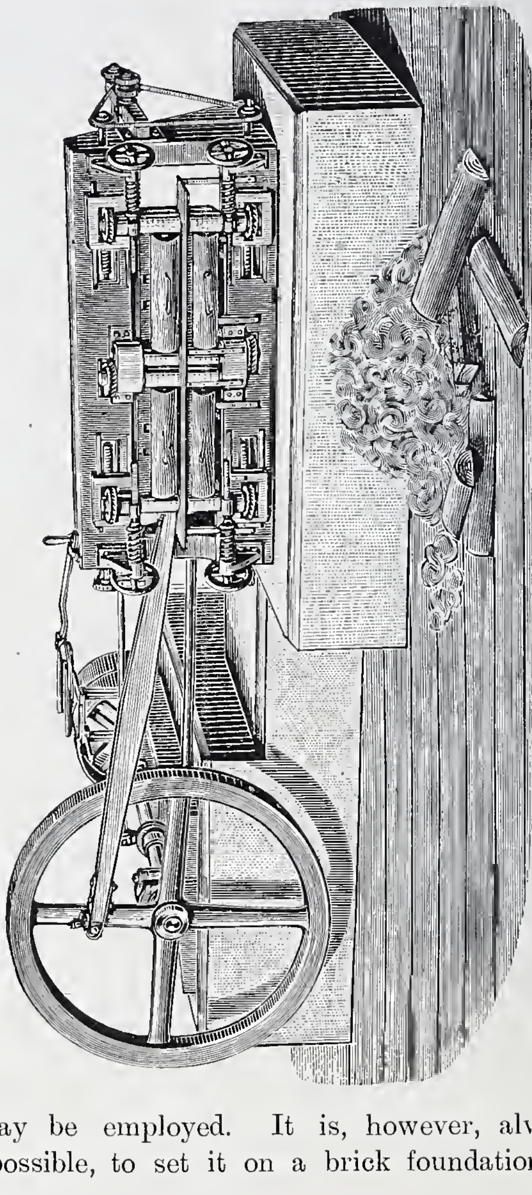

Fig. 48.—Quadruple Wood-wool Machine without Scribing Knives.

base may be employed. It is, however, always better, where possible, to set it on a brick foundation, as it will

then work steadily and quietly even at a high speed. Gearing and machine are connected by a wrought-iron connecting rod. All the shafts, etc., are of steel; the carriage runs in exchangeable and adjustable guides; the knives are arranged vertically, and are divided into two sets, each consisting of a plane cutter and a toothed knife, which works immediately in front of it, and acts on two pieces of wood. The one set of knives cuts during the forward motion, the other during the backward motion, but each of them on a separate piece of wood. The rollers are divided into three groups, the middle one of which consists of two fixed rollers covering the whole width of the carriage, and taking the thrust of the knives, whilst the two outer groups are divided in the middle, so that each short roller serves for holding a separate piece of wood and is separately controlled by a hand-wheel and screw. A thin plate divides the face of the plane into upper and lower halves; this serves at the same time as a bed for both the upper pieces of wood, and can be removed if thicker blocks of wood are to be worked up. The following additional parts are supplied with each machine:—

Interchangeable wheels for producing seven different sizes of wood-wool, varying from $\frac{1}{2}$ to $\frac{1}{15}$ millimetre in thickness. Two plain and two toothed plane knives of 12 or $13\frac{3}{4}$ inches long. The teeth are arranged for producing filaments 2 millimetres wide. To produce either wider or narrower filaments toothed knives of different sizes must be inserted.

Vertical Wood-wool Machine (Ernst Kirchner & Co.).

This machine is especially advantageous in places where there is but little space, or where the driving-shaft is high up, or where a cheap machine is required, from which an abundant output is not of special importance.

The machine is similar to the single-acting machine, with the difference that it is set up in a vertical position

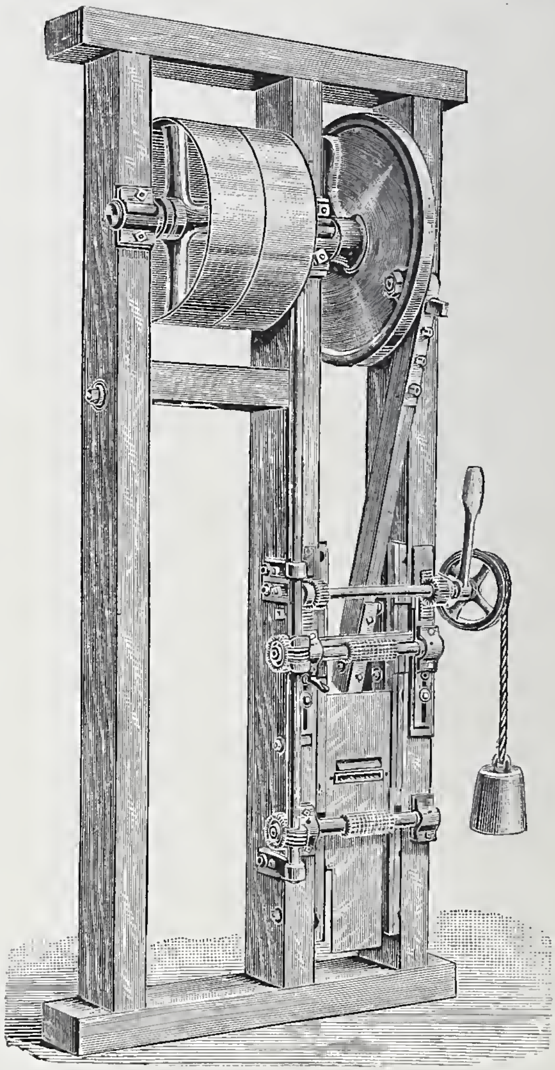

FIG. 49.—Vertical Wood-wool Machine (Kirchner & Co., Leipsic).

and is mounted on a wooden frame. In small establishments, where wood-wool is prepared, not as an article of

commerce but for home consumption, this machine will suffice in many cases. The machine is constructed with either one or two cutters. The figure shows a pattern with one cutter. In the machine with two cutters the fast and

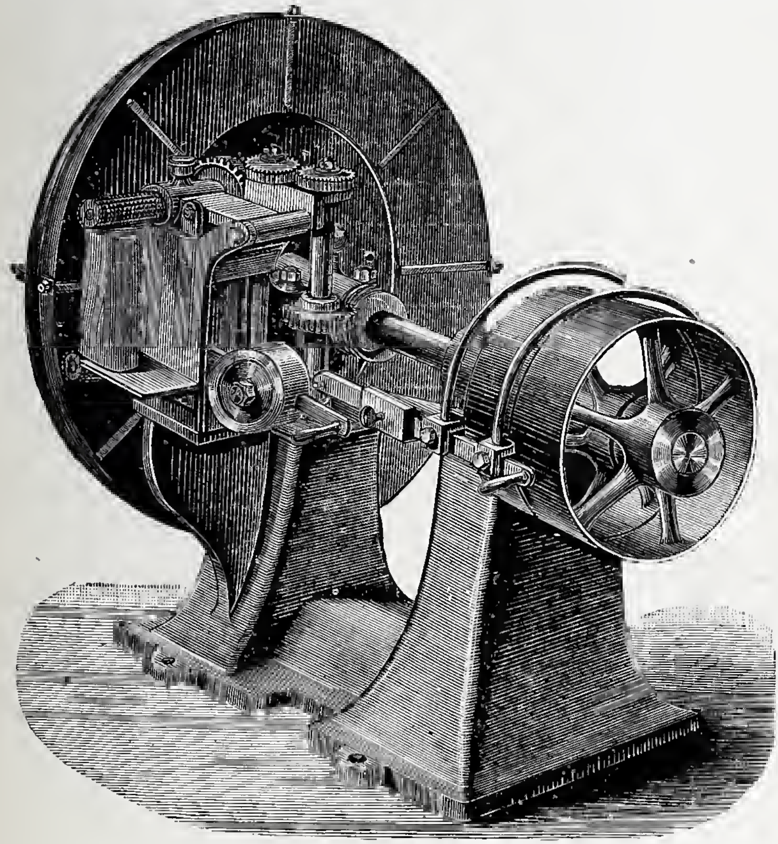

Fig. 50.—Rotary Wood-wool Machine.

loose pulleys are arranged between the two crank-wheels, so that there are cutters both to the right and left of the driving-pulley, and two pieces of wood can be shredded into wool at the same time. The cranks of the two crank-wheels are set 180° apart.

The machine is manufactured of three different sizes for pieces of wood up to 20, 24, and 28 inches in length. The force required is 2 to 4 horse-power.

Rotary Wood-wool Machine of Otto Camillo Israel, Vienna.

This machine is built with a strong cast-iron base, which enables it to be run at 250 revolutions per minute. In the vertical knife-wheel there are 4 sets of toothed knives alternating with 4 plain knives. A sheet-iron screen covers this knife-wheel and protects the workman from injury. The pieces of wood, 10 inches long by $4\frac{3}{4}$ inches thick, and of any width, are brought into contact with the knives by two grooved wheels. By changing the knife-wheels, seven sizes, and by changing the toothed knives, fourteen sizes of wool can be produced. The output is the same as that of a triple-acting machine.

Bark.

Tree bark, especially that of the oak and coniferous trees, and also of the birch, willow, and elm, is not to be regarded as a mere waste product, since in many places it finds extensive application as a tanning material.

Nevertheless, in localities where there are no facilities for carriage, bark must be looked on as a waste product which can only be utilised as fuel. In such cases it is, however, profitable to extract the tannin, the carriage of which presents less difficulty. This extract can be employed for tanning with the same result as bark itself, and since 100 parts of extract are quite as efficient as 400 to 500 parts of bark, it follows that its higher commercial value allows it to be delivered to the consumer at far greater distances than is the case with bark.

In his work on "Die Verwerthung des Holzes auf chemischen Wege" (The Utilisation of Wood by Chemical Methods) Dr. Bersch says: "In order that tannin extracts may meet with general approval by tanners, at least two conditions must be fulfilled: The extracts must invariably be sent out of the same quality and containing a definite percentage of tannin, and the tanner must be made acquainted with the mode of employing the new material. If the tanner can be assured that 1 lb. of the extract will have exactly the same tanning efficiency as a definite number of pounds of the best coppice bark, practical men will very soon accustom themselves to employ the extract instead of bark. The introduction of the extraction process furnishes, moreover, the proprietors of forest lands with a means of bringing the one valuable constituent of bark, *i.e.* the tannin, into such a form that it can be delivered at great distances, whilst the use of the extract affords the tanner the immense convenience of being able to work with rapidly prepared solutions of the material, instead of having, as formerly, first to extract the tannin from the bark. Furthermore, the large spaces required for the storage of bark, the drying of the spent tan, etc., are rendered quite superfluous."

In this connection I merely indicate here the mode in which the bark, when it has to be regarded as a waste product, can be utilised, whilst for further particulars respecting the preparation of tannin extracts the reader is referred to the above-mentioned treatise by Dr. Bersch.

Utilisation of Birch-bark.

The bark of the birch can be employed as a tanning agent in the same way as that of other trees. When birch-bark is submitted to dry distillation the usual products: gases, pyroligneous acid, and tar are obtained, but

the proportion of tar is somewhat considerable, amounting to about 60 per cent. of the weight of the bark employed. Birch-tar, or the product of its redistillation, birch-tar oil, has a very characteristic odour, which will be recognised as that of Russia leather, this leather being prepared with birch-tar. Fancy goods made from imitation Russia leather are also treated with birch-tar to give them the characteristic odour of the genuine article.

The distillation of the bark is best carried on in large iron pots, with an alembic head and cooling worm coil. In this way the pyroligneous acid and tar are completely and easily collected, and the distillate, when left in repose, separates into two sharply defined layers. Seeing that the yield of acetic acid from the distillation of bark is comparatively trifling, it is not worth while to work it up for the production of acetic acid at the spot, so it is collected and sent to factories where the manufacture of wood-vinegar is a special feature.

Besides these modes of utilising bark, it is used for architectural and decorative purposes. In forest districts, summer houses are either wholly built of bark or of a wood framework covered with bark; also baskets for plants in pots, etc., are made from bark, and command a ready sale.

THE END.

INDEX.

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